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THE JOURNAL

—OF THE—

FRANKLIN INSTITUTE,

DEVOTED TO

SCIENCE AND THE MECHANIC ARTS.

EDITED BY

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with the Assistance of

Dr. Wm. H. Wahl, Secretary of the Institute.

VOL. CXLVIII.—Nos. 883-888.

(74TH YEAR.)

JULY-DECEMBER, 1899.

PHILADELPHIA:

Published by the Institute, at the Hall, 15 South Seventh Street.

1899

JOURNAL OF THE FRANKLIN INSTITUTE.

Vol. CXLVIII.—July-December, 1899.

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JOURNAL

OF THE

FRANKLIN INSTITUTE

OF THE STATE OF PENNSYLVANIA,

FOR THE PROMOTION OF THE MECHANIC ARTS.

VOL. CXLVIII, No. 1. 74TH YEAR. JULY, 1899

Mining and Metallurgical Section.

Stated Meeting, December 28, 1898.

FELDSPARS AND KAOLINS OF SOUTHEASTERN PENNSYLVANIA.*

BY T. C. HOPKINS,
Member of the Institute.

FELDSPARS.

Feldspar, or spar, as it is commonly called by the quarryman, is a class or group name that includes several different mineral species, which have certain general resemblances sufficient to distinguish them from other minerals, and differ among themselves sufficiently to have different names. They all have cleavages in two similar directions inclined

*Based on field-work done by the writer during the summer of 1898, under the auspices of the School of Mines of The Pennsylvania State College, and is here given in advance of the College report with the consent of the President of the College.

to each other at an angle of 90 or nearly so. They crystallize in two systems, the crystals resembling each other in angle, habit, and methods of twinning. They vary in hardness from 6 to 6·5, in fusibility from 3 to 5, in specific gravity from 2·5 to 2·9. They vary in color from white to yellow, red, green, or dark.

The feldspars are for convenience divided into two classes:

(1) Orthoclase, the potash or acid feldspar, and

(2) Plagioclase, the soda-lime or basic feldspars.

All the feldspars are compound silicates of alumina and an alkali base. The silicate of alumina is common to all the varieties, the alkaline base consisting of potash, soda or lime, rarely baryta, varies in the different species. The first group is called acid because it has a high percentage of silicic acid. It is called orthoclase (meaning straight cleavage) because of the straight cleavage of two faces at right angles to each other.

Chemically, orthoclase is potash alumina silicate, $KAlSi_3O_8$ (K_2O, $Al_2O_36SiO_2$) consisting of silica (SiO_2) 64·7 per cent., alumina (Al_2O_3) 18·4, potash (K_2O) 16·9. Sometimes soda replaces part of the potash forming soda orthoclase, sometimes, in fact, the soda may be in excess when it forms anorthoclase, a triclinic form in which usually the soda is in proportion to the potash as 2 to 1 or 3 to 1.

Orthoclase differs from the other feldspars crystallographically in that it crystallizes in the monoclinic system while the others are triclinic. The crystal habit of orthoclase is generally prismatic or tabular, commonly with two well-developed cleavages. Twinning of the crystals is quite common and follows one of three laws known as the Carlsbad, the Baveno, and the Mannebacher, the distinctions of which are interesting to the mineralogist, but not to the tradesman.

The plagioclase feldspars differ from the orthoclase in being triclinic and in having, besides a twinning according to one of the above laws, another twinning in accordance with the albite or pericline laws. In both of the latter the twinning is usually polysynthetic, that is, repeated many

times, which causes a striation on either the basal pinacoid (the albite law) or the brachypinacoid (the pericline law). These striations may frequently be seen by the naked eye, but are best observed in the microscope. The microcline feldspar, which is chemically a potash feldspar, is crystallographically triclinic, and usually has both the albite and pericline polysynthetic twinning, thus giving a double striation on a basal section, producing the peculiar "window-grated" texture so characteristic of microcline.

The plagioclase group proper, or the soda-lime feldspars, include a series ranging from the soda feldspar, albite $NaAlSi_3O_8$, at one end to the lime feldspar, anorthite $CaAl_2Si_2O_8$, at the other. There is a more or less intimate gradation of the one into the other, but four other varieties are introduced between these two by drawing arbitrary lines at regular intervals. This makes the classification more detailed, but more complex and less definite. It would be necessary to draw one arbitrary line to separate albite and anorthite, but by introducing the four intermediate varieties there are four arbitrary lines to be drawn. The intermediate forms are oligoclase, andesine, labradorite and bytownite.

With this chemical change noted in passing through the series, there are corresponding crystallographic and optical changes which are interesting to the professional mineralogist, but have no special interest or value to the tradesman.

The point of difference which interests the manufacturer is the change in fusibility which is governed largely by its chemical composition.

The chemical and physical relations of these forms are best shown by tabulating them:

PHYSICAL AND CHEMICAL PROPERTIES OF THE FELDSPARS.

Name.	Ratio of albite 1 to anorthite *n*. 1 : n.	Hardness.	Fusibility.	Specific gravity.	Silica.	Alumina.	Lime.	Soda.	Potash.
Orthoclase.	—	6	5	2·57	64·7	18·4	—	—	16·9
Albite.	1 : 0	6-6·5	4	2·624	68·7	19·5	—	11·8	—
Oligoclase.	12 : 1	—	—	—	—	—	—	—	—
	8 : 1	6-7	3·5	2·64	65·7	21·5	2·4	10·4	—
	6 : 1	—	—	—	—	—	—	—	—
Andesine.	3 : 2	—	—	—	—	—	—	—	—
	4 : 3	5 6	—	2·69	57·4	27·1	8·9	6·6	—
	1 : 1	—	—	—	—	—	—	—	—
Labradorite.	3 : 4	—	—	—	—	—	—	—	—
	2 : 3	5-6	3	2·71	53·00	30	12·3	4	—
	1 : 3	—	—	—	—	—	—	—	—
Bytownite.	1 : 4	—	—	—	—	—	—	—	—
	1 : 6	—	—	2·74	46·6	34·4	17·4	1·6	—
	1 : 8	—	—	—	—	—	—	—	—
Anorthite.	0 : 1	6-6·5	5	2·76	43·2	36·7	20 1	—	—

The greater part of the feldspar that goes into the market is orthoclase, and one might expect it would have a uniform composition, but as shown from the following analyses of commercial spars the variation in composition is considerable, which is easily understood when we remember that orthoclase always has a variable percentage of soda and is accompanied by variable quantities of the soda-lime or plagioclase feldspars, and contains considerable but varying proportions of quartz and small quantities of other minerals, such as mica, hornblende, etc. The bulk of the foreign minerals is separated in the quarrying process, as far as possible, by careful hand-picking, but it is not practical to remove all. Moreover, as feldspar yields readily to the weathering agencies, there may be a considerable variation in the composition of the commercial product from different localities or from different parts of the same deposit, dependent on the degree to which this disintegration or kaolinization has taken place.

ANALYSES OF FELDSPARS.

Name.	Locality.	SiO_2.	Al_2O_3.	CaO.	Na_2O.	K_2O.
Orthoclase (?)	Embreeville, Pa.	67·46	21·76	1·67	5·96	4·28
Orthoclase	Bolton, Mass.	65·23	19·26	·42	2·98	11·80
Orthoclase	Brandywine Summit	65·61	16·92	·16	2·11	12·92
Albite	Unionville, Pa.	66·65	20·79	1·47	8·86	1·36
Albite	Mineral Hill, Pa.	66·34	20·72	1·85	9·44	0·98
Oligoclase	Wilmington, Del.	64·75	23·56	2·84	9·04	1·11
Oligoclase	Sanford, Me.	56·65	25·56	8·25	6·18	1·34
Labradorite	Labrador	56·00	27·50	10·10	5·00	0·40
Anorthite	Mt. Somma	43·98	35·30	18·98	·47	·40

Mode of occurrence.—Feldspar occurs as one of the constituents in a great many different rocks, in fact, in most of the granular igneous rocks and many of the metamorphic ones, in all of which it is associated more or less intimately with a variety of other minerals. While it is one of the most abundant and widely distributed minerals, the localities where it is segregated free from other minerals are comparatively few. The feldspar segregations where it occurs sufficiently pure for commercial purposes in Pennsylvania are in the form of pegmatite veins, or dikes, varying greatly in width and extent. The veins, or dikes,* are frequent in the gneiss and mica schist rocks of Delaware and Chester Counties. They are not limited to the micaceous rocks, however, as some large veins occur in serpentine rocks. The veins may vary in width from an inch or less to 50 feet or more. The actual length is difficult to determine, but, like most veins, they swell out quite large in places, between which enlargements they may be so much restricted as to either partially or wholly cut off the vein. As a result, the commercial spar is obtained from irregular, elongated, lenticular-like masses or pockets, sometimes close to each other, sometimes widely separated by an area of barren rock. As there may be a series of parallel veins, these pockets may lie side by side as well as end to end. In some

* To avoid repetition, I shall hereafter use the word veins, and those who think they are dikes may supply the words "or dikes."

cases there are sharply defined walls to the feldspar deposits, in other cases there appears to be a rough gradation from the spar to the country rock, with no sharp line of separation.

These segregations of feldspar are commonly known as pegmatites, "giant granite" or granitic veinstone.

Pegmatite, as first used by Haüy, in 1822, was synonymous with "graphic granite," that unique intergrowth of quartz and feldspar. In 1843 its use was extended by Delesse to include all the very coarse granites, and is so used to-day. It includes not only the coarse segregations of the granitic rocks, but corresponding types of other plutonic rocks as well, thus we have the syenite-pegmatite, gabbro-pegmatite, etc.

Besides feldspar, the other economic products obtained from the pegmatite veins are mica, quartz and a number of minerals containing the rarer earths. They are also the source of many fine crystals of a great variety of minerals that have no particular economic usage, as the conditions favoring the formation of the great feldspar crystals also favor the crystallization of other minerals.

In the feldspar districts these veins are always referred to as the feldspar or spar veins, but the feldspar is only one of the minerals. In most of the Pennsylvania spar quarries the other minerals that occur in large quantities are quartz, muscovite and biotite, the constituents of ordinary granite. The essential difference between the pegmatite and the ordinary granite is in the greater size of the crystals, but there is commonly a segregation of minerals as well, so that some portions of the vein will be nearly pure spar, other portions nearly all quartz, and other portions very rich in mica.

The great size of some of these separate crystals is truly surprising. Professor Crosby mentions * the frequent occurrence of feldspar crystals in the New Hampshire quarries 10 feet or more in length, and one fully 20 feet long; and Brögger † mentions some 33 feet long.

* "American Geologist," Vol. 19, p. 154.

† "Canadian Record of Science," 6, 57.

No such giants as these were observed by the writer in the Pennsylvania quarries, but those a foot or more in length are not infrequent.

*The Origin of Pegmatite.**—Much has been written on the origin of pegmatites, and consequently much that is more or less conflicting. The different theories might be grouped in three classes: (1) Those that suppose a purely aqueous origin; (2) A purely igneous one; (3) That they have an aqueo-igneous origin. All of these theories have had able advocates, and possibly there is an element of truth in each. It is possible, indeed it appears quite probable, that all the pegmatite veins have not originated in the same manner.

The first theory allies pegmatite veins with quartz veins, and explains their formation by water carrying the material in solution and depositing it in fissures or along certain planes. Some writers, particularly some of the earlier writers, assumed that the solutions were heated and came from great depths; others, particularly in recent times, advocate the lateral secretion theory, in which the materials are carried in solution to the veins from the surrounding country rock by waters of comparatively low temperature.

The advocates of the second theory argue that the pegmatites are injected igneous material. Professor Williams offers several strong points in evidence of at least some of the Maryland pegmatites being of igneous origin.

The third theory recognizes the solvent power of water and the active agency of heat and combines the two. It is a well-known fact that, in the presence of water, all the rock materials can be rendered plastic or pasty at a much lower temperature than by simple dry fusion, and, therefore, the rock material saturated with water is reduced to a semi-fluid condition at a moderately low temperature, in which the coarsely crystallized pegmatitic material is segregated.

A very little analysis will show that the last theory is

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* This subject is ably discussed by Prof. G. H. Williams in the "Fifteenth An. Report U. S. Geol. Survey," 1893-4, pp. 675-684, and by Prof. W. O. Crosby and M. L. Fuller in the "American Geol.," Vol. 19, page 148, 1897. Both articles are illustrated. The first treats more specifically of the pegmatites of Maryland and the second of those of New Hampshire.

simply a connecting link between the other two. The line between aqueous solution and aqueo-igneous solution is an arbitrary one, as is that between aqueo-igneous fusion and pure igneous fusion. Recent investigation appears to rather emphasize the aqueous end more than the igneous. The speaker favors the aqueo-igneous theory, believing that the water is a more important agent than the heat in the formation of the Pennsylvania pegmatites.

An extended discussion of these theories is not justified here, and those interested in pursuing the subject further are referred to the two papers mentioned above, where numerous references are given to other writers.

Method of Quarrying.—The spar is frequently partially disintegrated by the weathering agencies near the surface, where it can be readily removed with a pick and shovel. In many of the deposits these are the only tools used, as the weathering agencies have penetrated with sufficient power to open the cleavage planes and loosen the whole mass, so that it yields readily to the pick. In some places it is so far disintegrated that much of the feldspar is changed to kaolin and near the surface mixed with constituents of the surrounding rock. In such cases it is necessary to cleanse the solid fragments of feldspar from the dirt in which they occur. Where the material is dry this is sometimes done by screening it on a wire netting, such as is used for screening sand. Where the material is not dry enough to screen, it is washed with a stream of water. From the deeper parts of the quarry, where the surface impurities do not occur, neither washing nor screening is necessary. But in all parts of the deposit there is an admixture of other minerals, such as mica, hornblende, quartz, etc., which are broken out and separated by a careful sorting by hand from the quarried material. Where the spar is too hard to yield readily to the pick, powder is used to blast it loose.

Sometimes the quarry is extended downward with nearly vertical walls and the material lifted in buckets with the aid of a derrick, operated in some places by hand-power, in some places by horse-power, and sometimes by steam-power.

In some of the quarries one end of the quarry is carried down on an incline and the spar hauled out with a horse and cart. In two of the Pennsylvania quarries drifts were run in and the spar mined underground. In the one case the drift runs horizontally from the surface on a steep hillside. In the other case the drift was from the bottom of a deep pit, and it was necessary to elevate the material to the surface after it was brought from the drift. After the hand-sorting the broken spar is sent to the spar mill.

There are two spar mills in Pennsylvania, one at Toughkennamon, and a much larger one near Brandywine Summit. Some of the spar is shipped in lump to the mills at Trenton and East Liverpool, where it is ground.

The grinding is a two-fold process, the first part consisting in crushing the material to powder under heavy circular stones or rolls, two of which are mounted on a short horizontal axis, which is attached to a rotating vertical axis. The heavy stone rolls, turning on both the horizontal and vertical axes, run in a pan into which the spar is shovelled by a workman. The process is similar to the ordinary dry pan, except that the rolls are stone instead of iron, and the pan is smaller than the average dry pan. After being thoroughly crushed under these rolls, the material is put in a large iron drum or cylinder along with a mass of flint ("Norway") pebbles and revolved at a rapid rate for two or three hours, which reduces it to an impalpable dust, when it is ready for the potters' use.

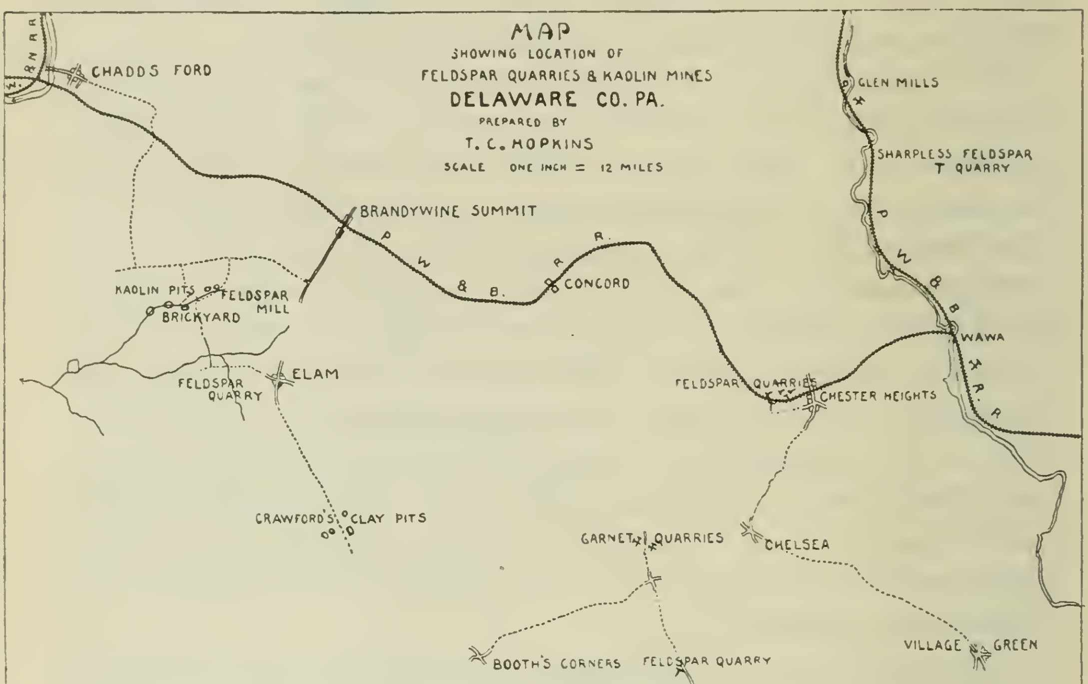
Uses of Feldspar.—Probably the principal use of feldspar is in china and porcelain ware, where it serves the purpose of a flux. It is used both in the body of the ware and in the glaze. It is used to some extent in making glass. It is also used in making enamelled or porcelain brick and enamelled tiling, where it serves the same purpose as in ordinary china ware. Small quantities are used by the dentists for making artificial teeth.

Distribution of Feldspar.—As the spar veins are limited to the gneissoid, schistose and serpentine rocks, the possible productive areas in this State are not large. All the feldspar quarries in Pennsylvania, so far as known to the

speaker, are in southern Delaware and Chester Counties. In 1898 there were ten companies operating seventeen quarries, and there are three other quarries that have been operated within the last few years.

The product of these quarries varies from one to ten tons of spar per day each, and it takes from two to ten men to operate each one.

In Delaware County there are feldspar quarries at Elam Post-office, Chester Heights and near Chelsea. In Chester County there are quarries at Avondale, Chatham, Unionville, Embreeville, Sylmar, Chadd's Ford and Fairville.



At Chester Heights the spar has been quarried from six different openings, and occurs as pegmatite vein deposits in micaceous rocks, the veins having a general northeast-southwest trend, varying in width from 8 to 20 feet, and standing nearly vertical. The quarries are 20 to 50 feet deep, except the last one opened (September, 1898), which is an underground working, and has been started on the vein near the base of the hill by running a horizontal drift into the hill following the vein. Some of the spar consists of graphic granite, some is nearly free from quartz, and from

one opening quartz was removed in large boulders; in fact, the dump has more the appearance of a flint quarry than a spar quarry. The spar is all shipped to the mill near Brandywine Summit.

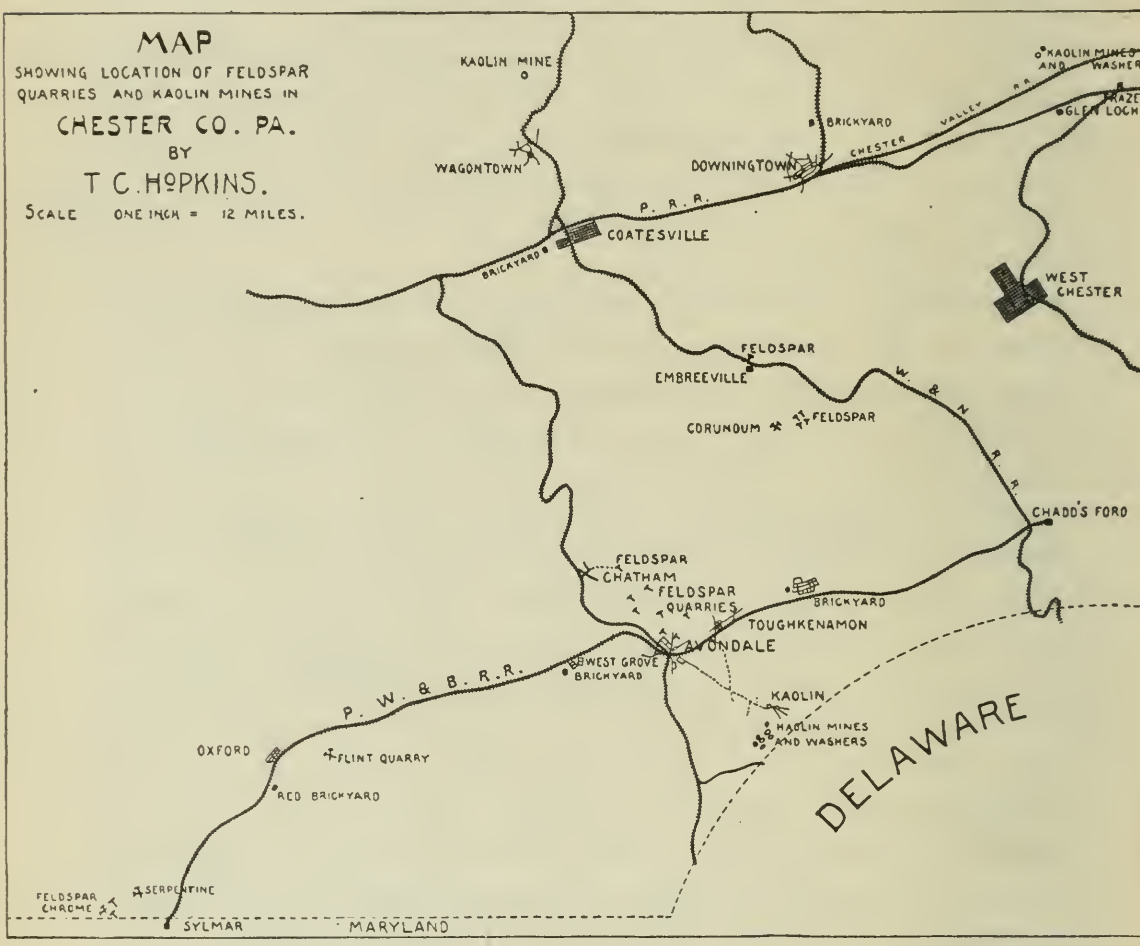
A feldspar quarry, known as the Sharpless quarry, about a mile south of east of Glen Mills, was operated a number of years ago, but is now idle. The spar contains large segregations of quartz and a great many large muscovite crystals, some of which are 8 to 10 inches across.

Near Boothwyn Station is a spar quarry that has been productive for several years. The vein is about 30 feet thick and the quarry opening about 150 feet long and 40 feet deep. The trend of the vein seems to be northwest-southeast, and it dips toward the southwest. Much of the spar is quite white in color.

Near Elam Post-office is the largest feldspar quarry in the State. It has been in operation fifteen years, and it is estimated that not less than 100,000 tons of spar have been removed from it in that time. The open working shows the vein to be 60 to 70 feet wide. It has been worked to a depth of 100 feet, and the opening is probably 200 feet long, but from the north end tunnels have been extended along the vein 100 yards or more further. The rock is partially kaolinized to a depth of many feet, and contains segregations of other minerals in considerable quantities in places; thus near the top of the opening muscovite is quite abundant, and near the bottom are large lumps of coarsely granular quartz. Carts are used to remove the spar to a depth of 20 feet or more. From the lower levels it is elevated to the surface by a derrick and steam hoist. It is hauled by wagon to the spar mill near Brandywine Summit.

Northeast of Unionville are several small feldspar quarries operated by companies outside of the State, one a Trenton company and one at Wilmington, Del. Feldspar was quarried from four openings during the present season, and there are not less than a half dozen other openings from which spar has been removed within the last few years. The openings are comparatively shallow, and appear rather as pockets than veins, although probably enlarge-

ments of veins, but the country rock has so disintegrated that the spar lies in the loose disintegrated material, and the vein walls are not clearly defined. The rock is a mica schist bordering on serpentine, and it appears that some of the quarries are within the serpentine area. Muscovite and biotite are quite abundant in places, and there is considerable diffused quartz, but no large masses were observed. These quarries are near the corundum mine,



where corundum was mined in considerable quantities several years ago.

The spar quarry at Embreeville is on the W. & N. railway, about 100 yards north of the Embreeville station. The vein, which is about 10 feet thick, crosses the railroad, and has been quarried on both sides of the railroad track. The vein appears to correspond in dip and strike to the garnetiferous mica schists in which it occurs, namely,

dipping 40° south, 60° east. The spar is nearly snow-white, slightly stained by dendrite markings in places. The analysis indicates a soda orthoclase with a slight admixture of a lime-bearing feldspar and considerable free quartz.

ANALYSIS OF FELDSPAR FROM EMBREEVILLE QUARRY.

SiO_2	67·46
Al_2O_3	21·76
CaO	1·67
Na_2O	5·96
K_2O	4·28

The quarry was first opened in 1885, and in 1886 produced 200 tons of spar ("Min. Res.," 1886, p. 701). The continuation of this vein southwest from the quarry is distinctly shown by the numerous outcrops at different points along the line of strike.

In the vicinity of Avondale there are four active and three idle feldspar quarries. They are all in pegmatite veins in mica schist, some of them in the immediate vicinity of limestone outcrops. The spar has a better defined pegmatite structure than that at any of the other quarries, that is, the quartz occurs intergrown on both cleavages of the orthoclase, giving the regular angular appearance of the ancient hieroglyphics.

Two of the most productive quarries are close to the village of Avondale on the north side of the village. The upper 10 feet of the spar are much decayed. The vein varies in width from a few feet to 31 feet. These quarries produced between 6 and 7 tons per day each during the summer of 1898.

About one and one-quarter miles north of Avondale is a large feldspar quarry with an opening about 120 by 40 by 35 feet in a pegmatite vein which has a general southwest-northeast direction and dips to the southeast. It was operated the first part of 1898, but was idle in the latter part of the summer. It has produced considerable feldspar, and, judging from the dump, there was considerable material handled to produce it.

There is another active quarry on the north side of the

Chatham pike, a mile or more northwest of Avondale, on the Thompson place, and another about half a mile further north, on the Dicky place, both of which contain typical graphic granite, and both of which were operated during the past summer.

The spar in the quarry near Chatham, about three miles west of north from Avondale, is different in appearance from that at Avondale. It has a nearly white color, and the quartz, instead of occurring along the cleavage planes of the feldspar, as in typical pegmatite, is segregated in large masses. The spar contains more plagioclase, and hence runs higher in soda and lime than that at Avondale.

The feldspar quarries near Sylmar, in southern Chester County, have considerable scientific interest in that, to the best of my knowledge, they are the only feldspar quarries in the world that occur in a serpentine rock, except, perchance, some of those near Unionville, Pa. The latter, if in the serpentine at all, are in the border close to the mica schists ; but in the Sylmar locality the spar is in the midst of a large area of serpentine, which outcrops on all sides of it. Small feldspar veins occur in serpentine elsewhere in the State, but, so far as known to the speaker, none of the others are of sufficient size to have any commercial value. The spar in these quarries is not a graphic granite, as there is no quartz present, and some of the spar has no well-defined cleavage. It consists of orthoclase, along with some albite and other plagioclase, associated with muscovite, hydromicas, hornblende and asbestos. The spar is well preserved, showing little evidence of decay, beyond a dull cleavage surface in places, and is frequently marked with a beautiful dendrite coating. The largest one of the quarries lies on a vein running nearly northwest and southeast (N50°W.). The opening is 30 feet wide, 35 feet deep and 150 feet long. At the south end the vein divides into two (whether permanently or whether only separated by a horse of serpentine is uncertain). Near the north end is a small vein branching off at nearly right angles.

The second quarry is about 200 yards southeast of the first on the line of strike of the vein, and probably on the

same vein, but there are no outcrops between the two to connect them. Chromite mines are operated nearby.

Where did this serpentine feldspar come from? A possible source is from a gneiss or schist underlying the serpentine, or from a former overlying one. Or it may have been a segregation in the rock from which the serpentine was derived; or it might have been produced from the rock from which the serpentine was derived.

As long as the origin of the serpentine itself is a question of dispute, we can hardly hope to satisfactorily explain the origin of the spar.

The feldspar quarries at Chadd's Ford and Fairville were not visited by the speaker, as he did not learn of their existence until he left the field work.

There is an abandoned feldspar quarry in Montgomery County, on the east bank of the Schuylkill River, between Lafayette and Spring Mill.* The quarry was opened in 1886, and 30 tons of spar removed and sold to the potteries in Trenton. The crude spar brought $5 per ton in Trenton.

The feldspar is orthoclase, with white granular quartz and large masses of biotite. It dips northward beneath the gneiss, and strikes transverse to the gneiss. The feldspar is at least 45 feet thick.

The deposits of feldspar that have been opened in Delaware and Chester Counties are probably but a fraction of the veins that might be worked, and Pennsylvania is likely to be a producer of feldspar as long as there is demand for the same, and the price is high enough to warrant exploitation.

The price of the crude feldspar, as it comes from the quarry, varies from $3.75 to $4.25 per ton, f.o.b. The price for the ground spar is about double that of the crude.

The production of feldspar in the State cannot be definitely stated, as some of the producers refuse to give the output of their quarries. A careful estimate by the speaker puts the amount for the year 1898 at 9,000 tons, which is

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* Described by Prof. O. C. S. Carter in "Proc. Am. Phil. Soc.," Vol. 29, 1891, p. 49-50.

probably a little less than the actual output, as no estimate was made for two of the companies from which no data were obtained.

KAOLIN.

One of the most common commercial products that result from the decay of feldspar is kaolin. The feldspars are compounds of silica with alumina and one or more alkalies. The alkalies are more soluble than either the alumina or silica, and on exposure to the atmosphere and meteoric waters they are leached out, probably by the action of carbonic and other acids, and at the same time water is added. In the process more or less silica is set free or forms new combinations, as the kaolin molecule has but one-third as much silica as the orthoclase. A hypothetical reaction, in which orthoclase is changed to kaolin, is as follows: $\underset{\text{(Orthoclase.)}}{K_2O,Al_2O_3,6SiO_2} + CO_2 + 2H_2O = \underset{\text{(Kaolin.)}}{Al_2O_3, 2SiO_2, 2H_2O} + K_2CO_3 + 4SiO_2$.

The potash is carried off in solution, and the kaolin and at least a considerable portion of the silica remain. Under varying degrees of temperature and pressure feldspars may undergo other transformations and different minerals result.

Pure kaolin, or kaolinite, contains 46·5 per cent. silica, 39·5 per cent. Al_2O_3 and 14 per cent. H_2O, but absolutely pure minerals do not occur in commercial quantities. Kaolin, being a secondary mineral, is liable to have not only the mineral impurities of the original feldspar, but an excess of silica that would result from perfectly pure feldspar, and frequently portions of undecomposed feldspar. There may also be impurities carried in by the meteoric waters.

There are two classes of kaolins, one the residual kaolin, that occurs in the position of the original feldspar as a residuum from the disintegration of the feldspar, the other a transported or sedimentary kaolin caused by streams washing away the residual kaolin and depositing it as sediment at some other locality.

Of the two classes of kaolins, the second or transported ones are liable, under the most favorable conditions, to be

purer than the residual ones, as the wonderful sorting power of water separates all the coarser and heavier particles contained in the residual material. However, the sedimentary deposits are liable to have impurities from other localities of material of the same degree of fineness, or of soluble materials, or materials that have segregated in or on the clay after its deposit. Hence the residual kaolins, while they generally have a smaller percentage of pure kaolin, are more likely to be a source of commercial supply than the sedimentary, because the foreign matter is mostly coarser material that can be separated by a mechanical process. The sedimentary kaolins, while frequently mixed with mechanically inseparable materials, do sometimes occur in commercially pure form, so that they can be used without any refining process, while others can be used like the residual kaolins after refining or washing.

There are several other minerals closely related to kaolin in composition and physical characters, so closely related, in fact, that they might, for the most part at least, be classed as varieties of kaolin rather than as separate materials. Some of these varieties have considerable local interest, some are of commercial importance, but most of them are of interest only to the mineralogist and are unknown to the tradesman. The chemical relations of these minerals to each other and to kaolin are best known by tabulating them:

Kaolin	$Al_2O_3,2SiO_2,2H_2O$	$= Al_2O_3$ 39·5 p. c.,	SiO_2 46·5 p. c.,	H_2O 14·0 p. c.
Halloysite	$Al_2O_3,2SiO_2,2H_2O + aq$	$= Al_2O_3$ 36·9 "	SiO_2 43·5 "	H_2O 19·6 "
Newtonite	$Al_2O_3,2SiO_2,5H_2O$	$= Al_2O_3$ 32·7 "	SiO_2 38·5 "	H_2O 28·8 "
Rectorite	$Al_2O_3,2SiO_2,H_2O$	$= Al_2O_3$ 42·5 "	SiO_2 50·0 "	H_2O 7·5 "
Cimolite	$2Al_2O_3,9SiO_2,6H_2O$	$= Al_2O_3$ 23·9 "	SiO_2 63·4 "	H_2O 12·7 "
Montmorillonite . .	About $Al_2O_3,2SiO_2.H_2O$, but varies.			
Pyrophyllite	$Al_2O_3,4SiO_2,H_2O$	$= Al_2O_3$ 28·3 "	SiO_2 66·7 "	H_2O 5·0 "
Allophane	$Al_2O_3,SiO_2.5H_2O$	$= Al_2O_3$ 40·5 "	SiO_2 23·8 "	H_2O 35·7 "
Collyrite	$2Al_2O_3,SiO_2,9H_2O$	$= Al_2O_3$ 47·8 "	SiO_2 14·2 "	H_2O 38·0 "
Schroetterite.	$8Al_2O_3,3SiO_2,30H_2O$	$= Al_2O_3$ 53·1 "	SiO_2 11·7 "	H_2O 35·2 "
Indianaite (nearly kaolin)		Al_2O_3 38·7 "	SiO_2 44·7 "	H_2O 15·0 "

Any of the above are liable to occur in small quantities associated with kaolin or allied minerals, but the only ones known to occur in commercial quantities are indianaite, halloysite and newtonite. Halloysite is mined in Ken-

tucky, South Carolina and Georgia (*Eng. and Min. Jour.*, October 1, 1898).

There are numerous other sub-varieties, such as smectite, bole, pholerite, guembelite, samoite, etc., which are mostly local in their occurrence and importance.

Both the residual and sedimentary kaolins occur in Pennsylvania in two rather widely separated fields—the residual ones in Delaware and Chester Counties and the sedimentary ones in Cumberland, Franklin and York Counties, and possibly elsewhere. There are eight kaolin-washing establishments in operation in the two fields, if we include one that is temporarily idle and one that has but recently started.

The residual kaolins occur in Delaware and Chester Counties. There were formerly two kaolin-washing plants operated in Delaware County, but now there is none. There are three in Chester County.

In the residual kaolins of Pennsylvania the most common impurities are undecomposed feldspar, mica and quartz, which are almost wholly removed in the washing or refining process, except, at times, some of the quartz, which is so finely divided that it is carried over with the kaolin. In some of the mines there is a small percentage of iron oxide in the clay that is not removed in the washing. Ordinarily, the yellow portion containing the iron oxide is thrown aside or put in as a lower grade. But on account of its usually greater plasticity it is advisable to use some of it at times to render the clay tough enough to handle.

Washing the Kaolin.—The method used in the Chester County washing plants is that with the common log washer and troughs. The process is based on the marvellous sorting power of water. One of the essential parts of the process is a horizontal shaft, set at intervals with short iron or wooden arms, which shaft rotates in a rectangular or semicircular trough, into which the clay and water are thrown. The arms on the rotating shaft break up the lumps of clay and stir it into a slip or mortar, which is carried away by the running water through a long trough, which is frequently about 700 feet long; but for convenience this is cut in sections, which are placed side by side, and the current

follows a zigzag passage. The aim is to so regulate the current of water that all the kaolin will be carried along and the other materials dropped in the bottom of the trough. The greater portion of the coarse sand and heavy particles are dropped in or close to the washer, and one or more sand wheels are inserted to remove it and prevent it from clogging the troughs. At intervals the troughs are opened and the sand scraped out. The water carrying the kaolin in suspension passes from the troughs into settling tanks, where, after the kaolin settles, the clear water is removed and the kaolin slip pumped into a hydraulic filter press, where most of the water is squeezed out.

The kaolin comes from the filter press in large cakes, which are further dried either in racks in the open air or on a dry floor. In many places the dried kaolin is shipped in sacks, but the Chester County producers load the material loose in the car.

Kaolin, Pa.—One of the oldest kaolin-producing localities in the State is that near Kaolin Post-office, in Chester County, where kaolin has been mined and washed since 1839. At present there are two companies operating mines, each turning out about 40 tons of refined kaolin per day. Nearly all the kaolin from this locality is shipped to the large potteries in East Liverpool, Ohio, and Trenton, N. J. Both of the companies make a partial use of the by-products. One company screens the sand, pulverizes it and sells it to the potters for ground flint. The other company uses the sand for making silica brick for furnace use. Yet, despite the usage made of the sand, there is a large accumulation of it at both works.

The kaolin deposit is about 40 to 50 yards wide, with at least one parallel vein, and possibly others. It is all mined from the circular shafts with the temporary timbering. The deepest shaft sunk was 130 feet, but even though the kaolin deposit is deeper than that, most of the shafts are sunk less than 100 feet, as it is claimed that the expense of hoisting the material more than that distance is too great to follow with profit. As all the openings are filled with waste material, except the ones in which work is carried on,

there are no exposures except the kaolin in the bottom of the one or two shafts in actual operation. Several large boulders of coarsely crystalline, partially disintegrated giant granite have been left on the surface in one place, and is the only solid rock in sight at the mines. The kaolin is a decomposed pegmatite vein in the mica schists, the structure of the kaolin showing its pegmatite origin. The apparent trend of the vein, as shown by the openings made by the two companies, is northeast-southwest, but neither the width nor the lineal extent can be accurately determined from the openings made, yet they are sufficiently numerous and scattered to show a large deposit of kaolin of good quality. Near the surface the kaolin has a buff or yellow tint due to the admixture of yellow soil from other rocks. The yellow color extends several feet below the surface in most places, although in a few places the white clay is exposed on the surface.

The Hockessin, Delaware, kaolin mines and works are but two or three miles south of east from the kaolin mines described above, and are closely related to them in the character of the kaolin and the mode of its occurrence.

Brandywine Summit.—To the reading public the Brandywine Summit kaolins are better known than any others in the State, because they are the only ones that have been described in the State reports. The Annual Report for 1885 of the Second Pennsylvania Geological Survey gives an illustrated and quite a detailed account of the kaolin deposits and washing plants at that place. They are now idle and have been for many years. As at Kaolin, there were two companies, each of which a few years ago produced kaolin of good grade in large quantities. Both the companies are in existence yet, under the same, or nearly the same, firm names with different personnel, but one is now producing feldspar, as already mentioned under that subject, and the other is manufacturing high-grade building brick from the refuse material from the former kaolin mines.

The reason offered for the abandonment of kaolin washing is that the best material has all been removed from near

the surface and, owing to the abundance of water in the mines and the low price of kaolin, it is no longer profitable to work the deeper parts of the deposit. One company ceased preparing kaolin seven years ago and the other, three years ago. There is thought to be large quantities of good kaolin yet remaining, but not in position to be worked with profit at the present time.

On the Crawford estate, about a mile southeast of Elam Post-office and two miles or more from Brandywine Summit, is a deposit of white clay of considerable extent. It has not been refined for use in china-making, but was formerly used in the crude state for making fire-brick and some of it shipped in the crude state to other points. The material has not been mined for several years, and so far as could be determined from the small exposures now to be seen, it occurs in a sedimentary deposit of recent age. The clay is said to be highly refractory and produced fire-brick of good quality, and was sought after for furnace linings. It is quite probable, from the appearance of the clay, that with proper selection and washing it might produce a fair grade of china clay. Near the clay deposit there is a large sand bank from which considerable sand has been shipped.

Glen Loch.—About a mile and a half north of Glen Loch Station, on the north side of Little Chester Valley, are a kaolin mine and washer that have been in operation for four years, except during the present summer (1898), when they have been temporarily idle. The mine is near the contact of the Chester Valley (Ordovician) limestone and the North Valley Hill sandstone (probably Cambrian). The sandstone outcrops a short distance north of the mine and the limestone a short distance south, but neither rock is exposed at the kaolin opening. There are numerous large masses of coarsely granular white quartz in and near the kaolin, and large masses of granular quartz containing crystallized wavellite. Near the kaolin mine is an old iron mine from which large quantities of limonite were removed years ago. Less than 100 yards north of east is another deep shaft that furnished some iron ore and a rare mineral, *ceruleo-lactite*.

The kaolin is exposed near the surface at the mine, but the owner states that exploration shafts show it to sink rapidly beneath a thick covering of loose material of sand and rock fragments both east and west from the opening. The same authority states that the kaolin vein dips north into the hill and hence runs under the iron ore which lies north of it.

The Glen Loch kaolin bears a remarkable similarity to the white clay deposits of South Mountain in its geological position, but differs quite materially in its chemical composition, as may be seen on comparing the analyses:

ANALYSES OF GLEN LOCH AND SOUTH MOUNTAIN KAOLINS.

	Glen Loch Kaolin. Per Cent.	South Mountain Kaolin. Per Cent.
Silica	51·90	73·80
Alumina	31·29	17·30
Lime	tr	·00
Iron Oxide	tr	·35
Magnesia	1·52	1·18
Potash	4·01	2·49
Soda	2·99	·20
Loss on ignition	8·90	4·69
Total	100·61	100·01

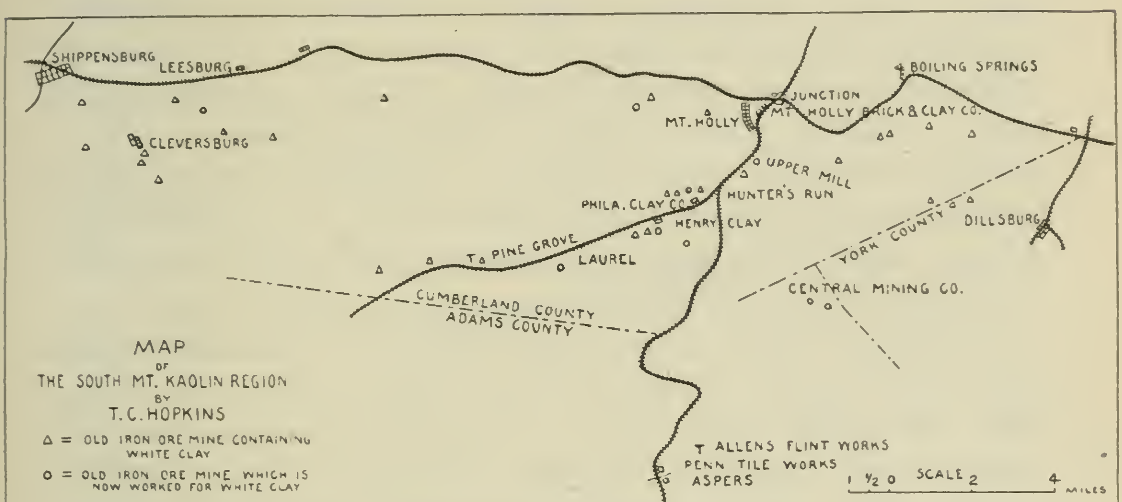
In Chester County, about two miles north of Wagontown, is an abandoned kaolin mine that was operated twenty years or more ago. A large circular opening about 100 feet in diameter and 60 feet deep shows that considerable work was done here at one time. The country rock is a hornblende gneiss.

SOUTH MOUNTAIN WHITE CLAYS.

Probably the most extensive deposits of white clay in Pennsylvania are to be found in the South Mountain region in Cumberland, Franklin, Adams and York Counties, between Dillsburg on the east and Shippensburg on the west. The most extensive developments have been on the Gettysburg and Harrisburg Railway, south of Mt. Holly, and on the Hunter's Run and Slate Belt branch railway.

Historical.—The occurrence of white clays in this region has been known for many years, but it was only a few years

ago that any attempt was made to put them to commercial use. There are a great many large iron ore mines in which the ore is associated with the white clay. In nearly all these ore mines, which were worked quite extensively years ago, the white clay was found, sometimes underneath the ore and sometimes overlying it. In the latter case it was necessary to remove the clay to get the ore, and it was dumped out as so much waste material, just as the ore is thrown aside at the present time where it interferes in the removal of the clay. In the reports of the Second Geological Survey of Pennsylvania bearing on this region there is mention of the white clays at nearly all the iron mines described, but there is no intimation of any possible



commercial value for them. At that time the ore was the commercial product and the white clay was waste material. The ore users were not clay workers.

The first attempt to make commercial use of the clay was about six years ago, when the Penn Tile Works was established at Aspers, about the same time or shortly after the brick works at Pine Grove began operation. About three years ago two clay-washing plants were established on Mountain Creek, between Pine Grove and Mt. Holly Springs. More than a year ago a clay-washing plant was started at Latimore, and this year, 1898, another large plant started at Mt. Holly Springs. There are other parties exploiting the region for good clays.

Mr. J. W. Ivery has probably done more to develop the clays of this locality than any other individual. It was he that started the works at Pine Grove, at Aspers, and one of the works near Hunter's Run, and he is now Superintendent of the works just started at Mt. Holly Springs.

The factory at Pine Grove manufactures ornamental bricks of different kinds. The white clay, along with some colored clay, is used simply as a bond, the body of the material being a black slate for their reddish-colored bricks, and a greenish talcose schist ("soapstone") for the light-colored ones. The slate is brought to the works by railway from the slate quarry about three miles southwest of the works; the "soapstone" is hauled by wagon from the quarry a quarter of a mile from the works, and the clay is brought by rail from Laurel Station, three miles away. By different mixtures of these materials, this company manufactures quite a variety of ornamental brick, of different colors, shades and sizes. The bricks are moulded by dry press machine, and stacked in the kiln without any preliminary drying. They have two dry press machines, with a capacity of 30,000 per day, but the kiln capacity is only 12,000.

At Henry Clay Station, on the Hunter's Run and Slate Belt Railway, about three miles below Laurel, near the large Henry Clay iron mine, is a clay-washing plant well equipped and capable of turning out 25 to 30 tons of refined clay per day. It has been in operation about three years. The clay is mined in deep shafts 90 to 100 feet deep on the mountain side, a mile or more east of the works, from which point it is hauled by wagon to the works.

At Crane's Siding, on the H. R. & S. B. Railway, one mile above Hunter's Run Station, is a clay-refining plant that has been in operation about three years, and turns out about two carloads, 50 to 60 tons of refined clay per day. The clay is obtained at the long since abandoned Crane iron ore mine, where it underlies the ore, but lies at a high angle on the steep south slope of South Mountain. The mining is done in underground galleries, and the clay run out on tram cars and tipped on a platform from which it is wagoned to the works. The refined clay is shipped to wall-

paper manufacturers and potters. They have also prepared some brown clay from the sludge from the iron ore mine. This branch of the industry has apparently been abandoned.

Near Latimore Post-office, on the south side of South Mountain, six miles south of Dillsburg, the nearest railway point, a clay-washing plant was recently constructed, and has washed 100 tons or so of clay, but the product has not been entirely satisfactory, and the company has not yet put any on the market. Part of the clay is mined near the works, and part is brought from another mine two miles or more north of the works. It is all very short in the grain, apparently high in silica.

The last company to begin operations in the South Mountain district has located its plant at Mt. Holly Springs, and obtains its clay in part from the Upper Mill, a station on the Gettysburg and Harrisburg Railway, and in part from the Henry Clay mine on the Hunter's Run and Slate Belt Railway. From the first point the clay is moved to the works on wagons. From the second it is taken on railway cars. The company has leased clay at other points in the vicinity, but is only working the two deposits at present. This company has one of the largest and best equipped clay-working plants in the State. They have the facilities for washing and refining the clay in large quantities, and they utilize the by-product from the refined clay to make white brick for building purposes. At the time of writing, the company has just begun operations. The machinery was first started in July, 1898, and the first kiln of brick was burnt in September. They expect to refine clay for the wall-paper, the pottery and tile trades, and use the screenings for making high-grade brick.

The refining process is different from that in the Chester County washing plants. In place of the log washer, large iron blungers are used to disintegrate and stir the clay to a thin slip. It is run first into large cedar tanks, where the coarse materials are separated and the clay slip pumped into other settling tanks, from which it is pumped into the hydraulic presses. The company now has nine blungers,

twenty-two large cedar tanks and eight filter presses in operation.

The Clays.—The clays of the South Mountain area are sedimentary clays and not formed from the decomposition of feldspar in place like the kaolins of southern Chester County. They are probably of Cambrian age, occurring near the contact of the South Mountain sandstones and shales of supposed Cambrian age, and the Cumberland Valley limestone of Lower Silurian or Ordovician age. The strata are so broken, crumpled and disintegrated that it is not possible in many places to accurately locate the position of the clay beds in the section. In so far as they can be located, they appear to be at or near the top of the supposed Cambrian rocks. They are closely associated with extensive deposits of iron ore. There are a great many large ore mines that were operated extensively a few years ago, and in all these mines that occur in or close to the mountains the white clay occurs in large quantities. In many places the clay is stained in streaks, bands and irregular patches by contact with the yellow, brown and red iron oxides. In some places the ore underlies the mass of the clay, and in other places it overlies the clay, which is the result of the folding of the strata. The iron accumulated on the top of the clay originally, probably derived in part from the overlying limestone, and in part from the associated schists. The meteoric waters percolating through the limestone leached out the iron and deposited it at and near the less permeable clay and slate beds underlying. Further disintegration of the rocks, and later folding and crumpling, aided to mix the ore and clay along the contact, and in the folding of the strata in places the folds were pushed beyond the perpendicular, thus reversing the relative position of the strata on one side of the fold. It may be observed that on the north side of the mountains, or the south side of the valley, the ore underlies the clay, while on the south side of the mountain, or the north side of the small valley, the ore overlies the clay. This may be seen at the Crane Siding mine, which is on the north side of the valley, and where the ore has been worked from the surface openings, and now the

clay is being mined from below and behind the ore bodies. The same condition prevails on the mountain east from the Upper Mill, where Mr. Musser has made several openings in the clay between the ore and the mountain, and while the openings are on the hillside above the ore openings, the strata dip south at a higher angle than the slope of the hill, so that the clay beds are carried underneath the ore.

At the Henry Clay mine and the mine at Laurel the ore dips under the clay at a high angle, and has been worked back until there was a covering of 30 feet or more of clay over the ore. The same condition prevails at the mines of the Reading Iron Company, south of Boiling Springs, where the underdipping ore has been worked back by open cut until the overlying clay was too thick to remove, and then the ore is removed by underground drifts run down the incline underneath the clay.

The structure is rendered more complex and difficult because (1) the rocks in some places are more resistant and the folds have not been overturned, and (2) in several places there have been faults or vertical misplacements of the strata. The difficulties are increased by the scarcity of the exposures of the rocks *in situ*, which is due to the fact that the quartzite rock is quite brittle, and hence much fractured in the folding, thus breaking into loose masses of fragments on exposure, and the slates weather into clays, which, on the steep hillsides, creep down over the surface rocks for long distances. Therefore, while the general structure of the mountains is a series of overturned folds pushed over towards the north, the irregularities due to faults and variations in the strata, further modified by weathering and eroding agencies, render the structure so complex that it is difficult to follow the different strata for any great distance with accuracy. Hence correlation of the different deposits is attended with considerable uncertainty. In the front range, wherever the sandstone or quartzite was observed *in situ* by the speaker, which was in several places, it had a uniform east-of-south dip, but in many of the old ore mines apparent northerly dips are recorded. These apparent variations may be caused by secondary and tertiary folds parallel

with the main one or by the creep of the clay on the hillsides.

The following observations, made by an assistant on the State Geological Survey, fourteen years or more ago, may be of interest in this connection, and as they may not be accessible to all our readers, we take the liberty of giving them.* Owing to the rapid weathering of clays, good exposures made at the time the mines were in operation were quickly obliterated and cannot be observed now, hence the value of observations made years ago as hints and helps now in exploiting the clays which were then "barren clays."

In the Big Pond banks† the southern part of the openings showed 22 feet of white clay (p. 1441).

The George H. Clever bank showed white, yellow and red clays associated with the wash ore (p. 1442).

The Pine Grove bank No. 1 has a large horse of white clay, which still (1886) occupies a place in the east workings, and excavations on both sides of this generally barren dome of clay show excellent ore. The north side of the cut shows a conspicuous amount of black clay (p. 1449).

At the Dunbar mine (R. Boyer) the main tunnel seems to have cut three distinct ore beds, none of them over two or three feet in thickness and separated from each other by an immense amount of barren clay (p. 1460).

At the Crane Iron Company's banks (Phil. Clay Co.) "the stripping, under the most favorable circumstances, amounts to about 20 feet, while toward the mountain, where their best ore is found, it is simply enormous and consists mostly of sandy blue and white clay."

A bore hole for water at the Lehman mine disclosed 340 feet of ore, 40 feet of blue clay, 30 feet of white clay and 25 feet of mountain clay to the Potsdam Sandstone, a total

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* These are quotations and abstracts from the report on the iron ore mines and limestone quarries of the Cumberland-Lebanon Valley, by E. V. d'Invilliers, in the "An. Rept. Geol. Surv. of Pennsylvania," 1886, Pt. IV, pp. 1411–1517. The same report is summarized by J. P. Lesley in the "Summary Final Report, 1892, of the Pennsylvania Geol. Surv.," Vol. I, but the summary omits most of the references to the clay.

† See map on page 23 for location of the different banks.

depth of 435 feet. A heavy white clay shows on the western extremity of the cut, similar to that seen at the Crane mine (p. 1462).

At Ege bank (Big Creek) "the gangue material accompanying these ores, and especially that thrown out of the trial pits, is frequently a greenish talcose slate called soapstone by the miners, many of whom state that the base of the ore-bearing clays is a reddish slate, beneath which no ore, but occasionally white barren clay, is found."

At the Heck bank, north of the wash ore deposit, lump ore is said to have been tested by drifts run into the mountain side 25 or 30 feet, beyond which nothing but white clay is found.

At the Muslin bank an "80-foot shaft was sunk in the center of an otherwise promising ore pit, which, however, only developed a stiff white clay through the entire distance" (p. 1483).

The developments at the present time, in fact, the developments twenty years or more ago, are sufficient to show that enormous quantities of beautiful white clays occur in this region, but they are associated with still larger quantities of lower grade clays, that are stained with the associated iron ores. The works erected during the last few years show that the commercial importance of the clays is now established. The developments will be still greater as the quantity and qualities of the clay become better known. Owing to the association of the iron ores with the clays, large quantities of it will be found in all the localities that are stained with the iron oxides, and the company with sufficient capital to use these lower grade clays along with the higher grade will have the advantage.

White clays in the Cambrian rocks are not peculiar to this portion of the South Mountains, but occur in other districts as well. Similar-looking clay has been found, but only slightly developed in rocks of the same age on Neversink Mountain, at Reading, Pa., where some one* has

* There was no one at the place at the time of my visit, August, 1898, and I could not learn the name of the owner.

opened a deposit of white clay similar in appearance to that at South Mountain.

The Glen Loch kaolin mines may be near the same horizon. A white clay somewhat similar in character, but in smaller quantities, occurs with some of the iron ores in the Nittany Valley. This is probably at a higher horizon, but may have the same source.

Large quantities of white clay are reported at various points along the Great Valley region from Massachusetts to Alabama.* Deposits of the white clay in Lehigh County are said by Professor Prime to be derived from disintegrating damourite slates, and analyses of the clays show close relation chemically to the Cumberland County clays just described.

The Uses of Kaolin.—Kaolin is used in the manufacture of chinaware, hence the name china clay.† It serves to furnish a highly refractory white body for the chinaware. It serves a similar purpose in the manufacture of white tiling, white brick and white clay ware of all kinds. Kaolin, or white clay, is used in large quantities in the manufacture of wall-paper and sized paper, the paper trade taking about the same quantity as the pottery trade. It is used in small quantities for other purposes, but the bulk of the product goes to the potteries and the paper manufacturers.

The output of the Pennsylvania kaolin mines for 1898 is not far from 20,000 tons. As some of the producers will not give their production, this is partly an estimate, but a conservative one, based on observations, reports of railway officials, and a comparison of the working force and facilities of the companies not reporting with those that did give their output.

The prices vary from $10 per ton for the best grade kaolin to $6 or $7 for inferior grades. The prices of one of

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* See "Tr. Am. Inst. Min. Eng.," Vol. 3, 1874-5, p. 410. The Brown Hematite Deposits of the Great Valley, by Prof. F. Prime, also "Proc. Amer. Phil. Soc.," May, 1872, and January, 1873, articles by Prof. J. P. Lesley.

† Some writers distinguish between kaolin and china clay by calling the crude product kaolin and the refined product china clay, but the distinction is not scientific nor is it universally adopted.

the companies are, No. 1 kaolin, $10 per ton, f. o. b.; No. 2, $8; No. 3, $7. However, the active competition among the different dealers causes a considerable variation and fluctuation in prices.

ANALYSES OF PENNSYLVANIA KAOLINS.

	SiO_2	Al_2O_3	H_2O	CaO	MgO	K_2O	Na_2O	Fe_2O_3
1. Glen Loch, Pa.	51·90	31·29	8·90	tr	1·52	4·01	2·99	—
2. Brandywine Summit . .	71·02	19·72	7·04	·32	·03	·27	—	1·58
3. " " .	67·71	20·53	7·78	·39	·04	·29	—	3·12
4. Chestnut Hill	67·10	20·10	5·90	·10	·70	2·	tr	3·9
5. E. Nottingham	46·34	36·32	13·75	·04	tr	·77	tr	·64
6. Kaolin, Pa.	—	—	—	—	—	—	—	—
7. Upper Mill, Mt. Holly .	84·05	9·44	2·18	·23	1·35	2·37	·28	·28
8. " " .	73·80	17·30	4·69	—	1·18	2·49	·20	·35
9. Mt. Holly Springs . . .	73·30	17·43	4·68	·02	1·28	2·99	·17	·37

No. 1 made by F. A. Genth, 2 and 3 made by J. B. Britton, 1874, 4 and 5 made by F. A. Genth.

Nos. 7, 8 and 9 made in chem. lab. State College; No. 7 the crude kaolin, 8 the refined kaolin, 9 refined kaolin mixture from Upper Mill and Henry Clay mine.

Stated Meeting, March 8, 1899.

SOME FEATURES OF THE STRUCTURAL DESIGN OF BUILDINGS.

BY WM. H. BURR,
Columbia University, New York.

(*Concluded from vol. cxlvii, p. 430.*)

Experience in modern high building construction during the past three or four years has shown conclusively that although such buildings are from one point of view fire-proof, their interiors are frequently very combustible. Both New York City and Pittsburg, as well as Chicago, can show conflagrations in which steel frames and fire-proof floor construction were but indifferent protection, at least to the interiors of the buildings. It has been conclusively demon-

strated that if a building is to be fire-proof in the true sense of the word, its interior trim and furnishing, so far as possible, must be of non-burning materials. Further than that the same experiences have demonstrated with equal conclusiveness that the iron and steel members of the building frame must be substantially protected from the immediate exposure to high temperatures. This end is not difficult of accomplishment. It is attained with reasonable facility by surrounding beams, columns and other metallic members by casings of terra-cotta or tile shapes so formed to fit the metal that, when once in place, the casing is continuous and sufficiently well locked and secured to retain its position under any ordinary fire experience. This is already accomplished in well-designed buildings, and has, indeed, become in the best practice quite an ordinary procedure. These terra-cotta or other equally efficient fire-proof casings should not be of a flimsy or unsubstantial character, but in general should be from 4 to 8 inches in thickness. They are frequently put on in two layers. It is essential that the material should be such as not to crumble and fail away under the temperatures produced in a burning building.

On the whole, experience seems to indicate that tile or terra-cotta partitions are less satisfactory under the conditions of a conflagration than steel studding with plastering on wire netting, as they are liable to crumble and go to pieces, particularly if struck by water, but such indications cannot yet be considered conclusive.

Perhaps that portion of fire-proof construction, requiring the most careful consideration from a structural point of view, is the floor of a building. The floors are horizontal and cover large areas, and if a fire is started it attacks them in such a way as to produce the most aggravated effects possible. Their horizontal position and large areas contribute to this result. At the same time they carry the own weight of the greater portion of the building and its contents and the moving load. They must, therefore, not only be fire-proof, but they may be subjected to heavy loading, while their fire-proof qualities are receïving the most severe tests. Their carrying capacities must, therefore, remain

practically unimpaired while they are subjected to simultaneous high temperatures and impact of fire streams. Many investigations of an empirical character have been made in order to determine materials and combinations of materials which can be depended upon to afford the desired security; and it may fairly be said that these investigations have at the present time been crowned with a considerable degree of success.

Probably the earliest investigations of the carrying and resisting capacities of fire-proof floors were those carried on in Denver, in 1890. In those investigations both hollow tile and concrete floors were subjected to test. The most complete series of such investigations of actual fire proof floors was that conducted by the Department of Buildings of New York City, in 1897, which covered a number of systems of construction, among which were all the more prominent ones used at the present time. The general method of procedure was the construction of a floor of any given design over a furnace area 14 x 16 feet or about 14 feet square. The walls of this furnace were of brick and two grates extended over the entire interior floor, one about eighteen inches above the other, on which were piled the wood fuel used for the high temperatures required. Each type of floor was constructed as a roof to the furnace and of the actual thickness and materials used in regular building construction. The various types of floor were constructed between rolled steel beams spanning the longest dimension of the furnace and from 4 to 5 feet apart, giving about the ordinary span found in fire-proof floors. The chief materials used were concrete, either cinder or stone, of various proportions and hollow tile of the usual terra-cotta character. The concrete was usually employed in combination with wire netting, reinforced with heavier wire rods about $\frac{7}{16}$ inch in diameter, or with some other light metal device of a character more or less similar to that described. In some cases the plastered ceiling was held on netting either suspended from a concrete arch above or secured by other means. In other cases, as in the Rapp system, the plaster on the under side of the floor, corresponding to the ceiling of a room, was ap-

plied directly to brick surfaces or others of a similar character. In all cases the lower flanges of the steel supporting beams were protected by plaster, or concrete, or terra-cotta shapes or plates so formed as to fit the flanges. The concrete used was made frequently with cinder, but sometimes with stone or gravel, and in one case at least the material between the rolled beams was made chiefly of plaster-of-Paris and wood chips, or other woody fiber. In each case the test consisted not only of subjecting these floors to high temperatures, running from 1,700° to 2,100° or 2,200° F., but while they were at these high temperatures, to the effect of a fire stream for the period of fifteen or twenty minutes. The duration of each test from the time of starting the fire to the end of the application of the water was about five hours, although the highest temperatures existed for a period of one or two hours less. These fire-proof tests were conducted with the utmost care in order to make their conditions correspond as nearly as possible with the materials and quality of labor used in regular building structure, and it is believed that the results were fairly representative of what may be expected in ordinary conflagrations.

After the cold fire streams had been thrown into the furnace and against the under side of the tested floors, a sufficient time was allowed for cooling and then careful examinations were made in order to ascertain in all respects the condition of the tested materials. A great variety and degree of results was naturally observed. I think it may be stated, however, that both concrete and hollow tile construction were found to be excellent fire-resisting materials. In certain quarters little faith has apparently been placed in the fire-resisting capacity of concrete made either with cinders or with stone or gravel. These tests conclusively demonstrate, if such a demonstration were needed, that the fire-resisting capacity of concrete is at least equal to that of the best hollow tile construction used at the present time. All the tested floors carried during their tests an extraneous load of 150 pounds per square foot, and practically all supported that load without undue deflection in view of the high tem-

peratures. After the furnace had cooled, the load of 150 pounds per square foot was increased to 600 pounds per square foot, and the greater load was generally supported in a satisfactory manner. Some of the plaster, both on wire netting and on other supports, frequently crumbled and generally fell off before the end of the test, particularly after the impact of the fire streams, which were thrown under a 60-pounds pressure. The under portions of the concrete in contact both with the high temperature and the cold water crumbled to a slight extent only, but on the other hand considerable portions of the lower surface of the hollow tile were destroyed, although generally without serious injury to the sustaining capacity of the floors as far as they were tested. In those cases where the concrete arches were formed over wire netting, the latter was found in general to stand well up to its duty. If any doubt existed in the minds of engineers and architects as to the fire-resisting capacity of concrete in floors, the results of these investigations should dissipate all such doubt. These experimetal results as to the fire-resisting capacity of concrete have been amply confirmed by the experiences of such fires as those in the Methodist Book Concern building at Pittsburg and in other actual conflagrations.

Another equally interesting and important series of fire tests is that which was begun in 1896 by a joint committee of the Tariff Association of New York, the Architectural League of New York and the American Society of Mechanical Engineers. That committee was intrusted with the testing of cast iron and steel columns under a high temperature, both without and with the application of fire streams. The committee has thus far been able to perform but a portion of its assigned duties. It has tested under the conditions described one steel box column composed of two 12 x $\frac{1}{4}$ inch plates and two 10-inch channels riveted into the common closed form, the length of the column being 14 feet and its area of cross-section 15 square inches; 1 Z-bar column composed of four 4-inch Z-bars and one $6\frac{1}{2}$-inch x $\frac{5}{16}$-inch plate, the length of the column being 14 feet 1 inch, and its area of cross-section 14·15 square inches; and three

hollow round cast iron columns, each 13 feet long, 8 inches in exterior diameter, with 1 inch thickness of metal, the area of the cross-section being 21·99 square inches. The first, or steel box column, carried a load of 96,120 pounds at a maximum temperature ranging from 1,200° to 1,250° F., at which the metal began to show red. At this maximum temperature its ultimate resistance was 6,408 pounds per square inch, whereas, at the normal temperature, it should have carried about 42,000 pounds per square inch. The thickness of metal of this column varied from $\frac{1}{4}$ to perhaps $\frac{5}{16}$ of an inch in the most exposed portions. The second, or steel Z-bar column, carried a load of 169,600 pounds at a maximum temperature ranging from 1,200° to 1,375° F., at which the metal showed red. The load sustained by the column per square inch was therefore 11,986 pounds, while its ultimate resistance at an ordinary temperature should have been about 39,800 pounds per square inch. The thickness of most exposed metal was practically $\frac{5}{16}$ of an inch. Both the preceding tests were without any application of water.

The first cast iron column tested carried a load of 169,600 pounds at a maximum temperature varying from 1,200° to 1,250° F., at which it showed slight redness. The ultimate resistance of the column at this high temperature was 7,713 pounds per square inch, while, at normal temperature, it should have carried 27,380 per square inch, as measured by the results of the tests of full-size cast iron columns at Phœnixville, Pa., and Watertown, Mass. This test was also without water. The fourth was a cast iron column test, and practically a repetition of the preceding in all respects, except that the maximum temperature reached 1,550° F. under the maximum load of 169,600 pounds, at which it was broken suddenly. The fifth and last test was of a cast iron column, practically identical with those used in the two preceding cases, and was a combination of high temperature with the application of a fire stream. The column was first raised to a temperature of 525° F., when water was thrown on it for one minute. The temperature was then raised to 1,000°, after which it was lowered to 400°, when

water was thrown on the column for one-half minute. The temperature was again raised to 1,050°, at which the column showed red, when water was again thrown on it for one-half minute. The temperature then fell below 750°, but was again raised to about 1,300°, when water was thrown on it for one minute, and immediately thereafter for two minutes. When the water was thrown on the metal the last time it was decidedly red. The column was badly bent, but not broken. The duration of these five tests varied from about thirty minutes to two hours and fifteen minutes each.

It appears from these investigations that the cast iron column at a temperature of from 1,200° to 1,300° carried a little less than one-quarter of its ultimate resistance at ordinary temperatures, while the steel columns in the one case carried practically the same proportion of its ultimate resistance at ordinary temperature, and a little more than one-seventh in the other case. When it is remembered, however, that the thickness of metal of the steel columns practically did not exceed $\frac{5}{16}$ of an inch, while the cast metal had a thickness of 1 inch, it may be fairly stated, I think, that, other things being equal, the efficiency of the steel column is at least as high as that of the cast iron in carrying loads at high temperatures, although it still remains for that conclusion to be either shaken or confirmed by further tests.

In these tests the steel and cast iron were exposed directly to the high temperatures, whereas numerous experiences in actual conflagrations have shown that when iron and steel columns and girders are feasibly protected against direct action of high temperatures, their carrying capacities are not often sensibly diminished.

A few isolated instances of late building construction indicate a line of development of no little interest and possibly of considerable importance. Reference is made to construction of the walls and partitions of buildings of combined concrete and wrought iron or steel. A few small buildings of this character have been built in California by the Ransome process, in which twisted square rods have been imbedded in the concrete in order to give tensile resistance. Pos-

sibly a beginning has been made in Chicago by the same process, while a building devoted to manufacturing purposes was constructed at Bayonne, N. J., last year. The combination of Portland cement, concrete and steel rods, netting or other light members yields a mass of great resisting capacity which, at the same time, lends itself readily to manifold structural demands. It may form the body of the wall with a brick, terra-cotta or stone exterior in any ornamental design, or, in many cases, as in those named, it may constitute the entire wall. We are but just beginning to realize what a valuable structural material we have in concrete, particularly when it acquires considerable capacity for tensile resistance by the introduction of light steel reinforcement, as in the Ransome method and in the Melan, Monier and other systems of arch construction. With the excellent domestic Portland cements now available at economic rates, and with such advances as that exemplified by the production of silica—Portland cement—no less than by our knowledge of improved methods of concrete making, the field of application of concrete construction is widening rapidly. It is quite possible that the extending limits of that field may soon include monolithic-steel building, characterized by both economy and endurance. The materials are admirably adapted to such an end, certainly at all usual temperatures, since their rates of thermal expansion and contraction are practically identical. New problems of construction of more or less difficulty will undoubtedly arise, but if there should ever be a demand for their solution they will certainly be solved.

DISCUSSION.

WM. COPELAND FURBER:—Professor Burr's comprehensive discussion of this subject leaves but little to be said. His ideas, as set forth here to-night, endorse the best modern practice, regarding which there should be but little room for differences of opinion; but notwithstanding our knowledge of design there seems to be a lack of care or knowledge in the preservation of the iron skeleton from corrosion.

On the question of rust protection I may be taking

advanced ground when I say I believe that entirely too little attention has been paid to this matter by designers; yet the liability of corrosion is so great through exposure and improper covering and the lack of preparation of the metal to receive and hold the covering that I think the use of the sand-blast or some equally efficient means to remove the mill scale and permit the direct application of the protective covering to the actual surface of the metal is not only justifiable but imperative. When the skeleton is once enclosed examination is difficult, and repair practically impossible; and as the life of the building is coincident with the life of the framework, and the value of the investment is determined primarily by the integrity of the finished structure, a short-sighted and temporarily apparent economy should not be allowed to curtail a proper expenditure on the skeleton, which if intelligently made, will assure the building a practically indefinite existence.

As to the best means of providing against rust, the information already at our disposal seems to me sufficient to indicate a safe course to pursue. Ledebur, in his handbook, pp. 277–281, in an "Essay on Oxidation of Iron and its Admixtures, Rusting and the Influence of Liquids upon Iron," points out that three factors are required to produce rust—that is, the hydrated oxide, viz.: water, pure oxygen and an acid. Portland cement by furnishing a base for the absorption of any acid likely to be found, will eliminate one of these factors, and will thereby prevent rust. So that with the other valuable qualities it possesses it forms a protective covering of great value. But while this is true if the cement is in direct contact with the metal, we know that as the shapes come from the shops they are covered with mill scale, and that any covering applied to them adheres to the scale, and that a mechanical separation of the scale is easily possible.

Should water penetrate the cement or other covering, through cracks, and find its way between the scale and the actual surface of the metal, the scale being electro-negative to the body of the metal, the elements of a battery exist, and the degree of corrosion is a matter of time.

We also know that as concrete is frequently put in place the voids are not filled up and spaces are left for the accumulation of water, which may be present, forming with the scale already there, rust-producing factors.

It is not an uncommon thing where iron footings are placed below the water level to find that the water has dissolved and washed out all the cement which the concrete originally contained. I have seen more than one building standing with its "feet" wet, the cement having been washed out before the concrete set, leaving but the stone and sand remaining.

I believe, and have followed it out in my own practice, in placing all iron above the line of saturation if at all possible, and in the Harrison Building, which has been referred to here to-night, and for which I was the designing engineer, the grillage of I-beams in the footings is above the water level, the foundations below this being entirely of concrete; but when, for any reason, the grillage or underground metal work has to be placed below the water level, most extraordinary care should be used to see that the metal work is free from scale and unpainted, that the trenches or pits are so lined that no part of the excavation comes in contact with the beams, that the concrete contains a large proportion of cement with the aggregate or "filler" in small particles, so as to allow being rammed easily into a dense mass without voids. In the placing of long girders underground it is not an uncommon thing to see the earth fall in around the girders, and to see the concrete filled in without the earth being removed. It is needless, perhaps, to say that whenever this occurs a "fault" is formed in the concrete, and rust must inevitably follow.

On the structural work above ground the danger of corrosion is not so great, but is sufficient, I think, to warrant the use of a concrete envelope around the columns and external girders, for the masonry covering is not always thick enough or tight enough to exclude moisture. If concrete is used, the metal work should be temporarily protected by a coat of oil, which will be worn away by the time the building is ready for closing in.

Regarding column sections much remains to be said, and the selection of a closed or open section is, I think, an open question. The closed section is undoubtedly the better, both economically and structurally, but the difficulty of protecting the metal from corrosion is greater.

I have seen instances where the closed section held the rain collected during erection, which, with the drillings, cuttings and débris, which also found ready lodgment therein, supplied the elements for rust. A very interesting discussion on the subject of rust-prevention can be found in the Proceedings of the Engineers' Club of Philadelphia, Vol. XII, p. 225.

Wind-bracing is given by Professor Burr the attention its importance deserves, and, in view of the possibility of the accurate determination of the stress caused by an assumed wind pressure, it seems shortsighted and unwise to neglect provision for it in proportioning the structure. Outside of the increased stability and permanency it gives the building, it has the great merit of facilitating the erection, by permitting the columns to be retained in their correct vertical position, and in high buildings this is a matter of considerable difficulty.

Wind-bracing is frequently omitted because the architectural treatment adopted does not permit its use, and for this reason existing there is little justification. A rational and intelligent architectural designer can fit the architecture to the requirements of proper engineering design, and his failure to do so is a reflection on his knowledge and ability. Architectural traditions call for the exercise of few qualities beyond an academic conservatism, but the modern development of structural design has been carried forward without precedents, and its growth should not be restrained because the old architectural clothes will not fit it. The architectural treatment should follow the structural design, not prescribe it.

The fire-proofing of the metal frame work has not yet been brought to perfection, and the method of applying the various coverings now in use leaves much to be desired.

The high fire resistance possessed by Portland cement,

makes it an excellent fire-protecting material, and I believe, if properly applied, answers all the purposes of fire-proofing and rust prevention.

Portland cement, combined with a wire mesh to give it fibrous properties, is practically indestructible under the conditions likely to be encountered in a strictly local fire, and for column and girder coverings is the best material I know of, but the ease of its application makes it particularly liable to suffer from the evils of poor workmanship, and the most rigid inspection is required in mixing and applying it to secure the desired results.

For floors, I believe the porous terra-cotta tile with ample covering on the flanges of the beams is the best practical sort of a floor. In this the evil of poor workmanship is reduced to a minimum, and with any sort of efficient inspection poor results can be guarded against; whereas, with a concrete floor, a poor batch of concrete may lead to unpleasant results. The necessity also for using an aggregate or "filler" in the concrete, of a material like ashes, for lightness, is an objection of some importance.

The protection against fire by a comprehensive system of water-piping, arranged so as to distribute a sheet of water over exposed walls, has received little attention so far; with such a system protected against freezing on external exposures, and an efficient pumping plant, I am sure the Home Insurance Building, in New York City, could have been protected from serious loss. The Harrison Building, in this city, shows an attempt made in this direction.

When the problem of large building design is looked at from an economic standpoint, and the co-relation of the tenant and owner is considered, the solution of the question of providing the necessary facilities for office room, and the distribution of light, heat, ventilation, water-supply and elevator service for the comfort and convenience of the hundreds of tenants, with the greatest efficiency, becomes an engineering problem of great importance. And as the extent and permanency of the investment as a continuous interest-earning proposition depends upon the best solution of engineering features, structural and mechanical, the

whole matter is raised above that of mere architectural expediency to one of public policy.

A too great, insufficient or unwise expenditure reacts on the owner and tenant, finally on the community, to the detriment of each.

In conclusion, I would say that I believe that the highest results will not be realized until the engineer is recognized and granted his place in the primary design of the building, and the architectural treatment is co-ordinated to its rightful place.

Mechanical and Engineering Section.

Stated Meeting, held Wednesday, March 9, 1899.

MECHANICAL APPLICATIONS OF COMPRESSED AIR.

(Abstract of remarks by Mr. W. L. SAUNDERS, M. Am. Soc., C.E., Member of the Institute, in opening the discussion.)

MR. SAUNDERS :—I fear that your Secretary is treading upon dangerous ground when he puts me on tap so early in these proceedings. I once heard the question asked, what is the difference between electricity and compressed air? The answer was given in this way: They are both things that we know very little about, and the men who think they know most about them are the ones who make the greatest number of mistakes in talking too much about them; but there is one difference between them which everybody understands: An army of men may be killed one after the other by touching a live electric wire, while with compressed air, when the bottle once explodes, it dies in the attempt.

This is a very broad subject. Though one of the oldest of the sciences, compressed air in its practical application is one of the youngest. It is my purpose to touch but generally upon this subject, more in the line of an introduction than otherwise, but I shall have to ask your pardon when I go back more than a century before Christ and do honor to

our first pneumatic author and inventor, Hero, of Alexandria. Hero's fountain is but a jet of water sustained by compressed air. He describes in his work on pneumatics a pump or fire engine, in which the elasticity of air was an important feature. Hero also describes an invention of Ctesibius, consisting of a tube out of which an arrow was shot by means of compressed air—an early suggestion of the dynamite gun. This philosopher is said to have put into practical operation an invention by which the opening and closing of temple doors was effected by the alternate expansion and contraction of air when brought in contact with heated and cooled surfaces of altar tops.

We may now pass over centuries of the world's history, coming down well into the sixteenth century without finding any important practical applications of compressed air. The diving bell, so useful in building foundations for bridges, was perhaps the first really important use of compressed air; but with the exception of a few obscure instances we must get well into the nineteenth century in order to find compressed air generally used in caisson work. Beginning with the work of Rennie, in 1812, we have the records of Cubitt, on the Rochester Bridge, England, and Brunel in the Thames Tunnel. From bridge and tunnel construction, compressed air was extended in usefulness to mines and quarries, next to railroads, foundries, machine shops, acid factories, steel works, lifting and purifying water, and in numerous other useful applications of less importance.

Let us stop to consider how important some of these applications are. It is difficult to conceive the possibility of extensive bridge construction without the use of compressed air, and need we stop even for a moment to question how far in this respect alone compressed air has aided in the world's progress. The construction of great tunnels has been made possible by compressed air. This line of usefulness is not confined to railway tunnels, but to aqueducts and mines. The building of the New York Aqueduct, 30 miles in length through solid rock in three years is a recent example of the usefulness of compressed air. It is not an

uncommon record for a tunnel to be built by compressed air machinery in one-third the time and at one-half the cost when compared with hand labor. This means that in mines ores of low grade which otherwise might not pay, are made useful to the world. Think, for a moment, how much compressed air may have aided in the wealth of nations by increasing the production of the precious metals!

The largest application of compressed air is in connection with railroads. We may say with safety that air is supreme as a brake. More than 30,000 locomotives are equipped with air brakes, and it is doubtful if there is anything since the invention of the locomotive which has been of such importance to railroads as the air brake. It has not only increased facilities for transportation, but it has saved thousands of human lives.

Later on we will refer to other useful applications of compressed air in railway service, but here let us stop to give proper place in importance to the use of air in making steel. This has been called a "revolutionary use of compressed air," and by some it is considered its most important application. The Bessemer convertor uses air under pressure and forced through a mass of melted iron to burn out the carbon and thus convert cast iron into steel, making it possible to produce steel at a lower cost than iron. The enormous increase in the use of steel for rails and structural work generally may be laid to the Bessemer process.

Compressed air can be produced best and cheapest by the use of compound, condensing steam engines driving air pistons which compress the air in stages, intercooling between each stage. The rules which govern steam economy generally apply with equal force to the Air Compressor, and it is just as important to use compound air cylinders as it is to use compound steam cylinders. Air may be compressed to any practical pressure. Our experience with it is usually at pressures under 100 pounds per square inch, except in storage service, where it is used at 2,500 pounds per square inch. It is just as easy to compress air to higher as to lower pressures, it being simply a question of proper design of machine, but the higher the pressure the greater

should be the number of stages of compression, and the greater the importance of intercooling between stages.

Air transmission offers few if any difficulties except where it is desired to transmit large volumes great distances, and the trouble in such a case is only that the cost of the conduit makes the installation prohibitive from a commercial standpoint. Long distance electric transmission has been made to pay only when the current is transmitted at high voltage, and the same rules govern compressed air; it is

FIG. 1.—Car wheel and axle hoist.

best to transmit it at high pressures because we get a larger volume in proportion to the diameter of the conduit. At the present time our experience with pipes carrying compressed air at high pressures is so limited that long distance air transmission at high pressures must be said to be still in the experimental stage. The experiments, however, apply almost entirely to the mechanical construction of the conduit. We need pipes built for the purpose, and joints of proper construction to prevent leakage. It is a popular error, however, to suppose that there are any large losses

suffered in compressed air transmission. In practice, the losses suffered by transmission are so low that they are not taken into consideration. This is, of course, mainly due to the fact that the pipes are properly proportioned, and the distances traversed are not great.

To return to the practical applications of compressed air.

Air Brakes.—The best known type is that of the Westinghouse, where the air is compressed at the locomotive and conveyed to storage tanks on the cars. For street car service, air is compressed on the car by means of a small electric motor, operated through the axle. Another system has recently been introduced at Detroit in which no compressor is used on the car, but the air is stored at high pressure and is used through reducing valves to release the brakes.

Air Hoists.—These hoists are commonly used in railway yards and shops, foundries and machine works. The illustration herewith shows the hoist applied in a railway yard for lifting car wheels. These hoists are divided into two classes, the direct and indirect lift. The most popular type is the direct lift, and consists mainly of a cylinder or pipe in which is inserted a piston, the rod of which is attached directly to the weight to be lifted, compressed air is used directly upon the piston. The other form of hoist is shown in *Fig. 2*. By means of a little engine a pinion is turned in a lifting block and the load lifted by the differential pulley method.

Various modifications of these hoists are in use. In some cases the cylinder is placed in a horizontal position and the load lifted through a rope connected to the piston rod and passing over one or more pulleys. These hoists are of especial advantage, because of their simplicity, quickness of action and availability. They are usually applied to light loads under 1 ton. Other forms of air hoists are shown in the accompanying illustrations.

Pumping Water by Air.—Two systems are in use, a direct application of compressed air to liquids in wells, commonly called the Pohlé system, and the displacement pump system. The two have distinct applications: the first is a well pump, requiring deep submergence, and the second is a means by

which one or more vessels filled with liquid are submerged in the liquid to be raised, and compressed air is applied to the surface of the liquid in the vessel, forcing it to any desired point. The displacement pump system is used in sumps and for raising acids.

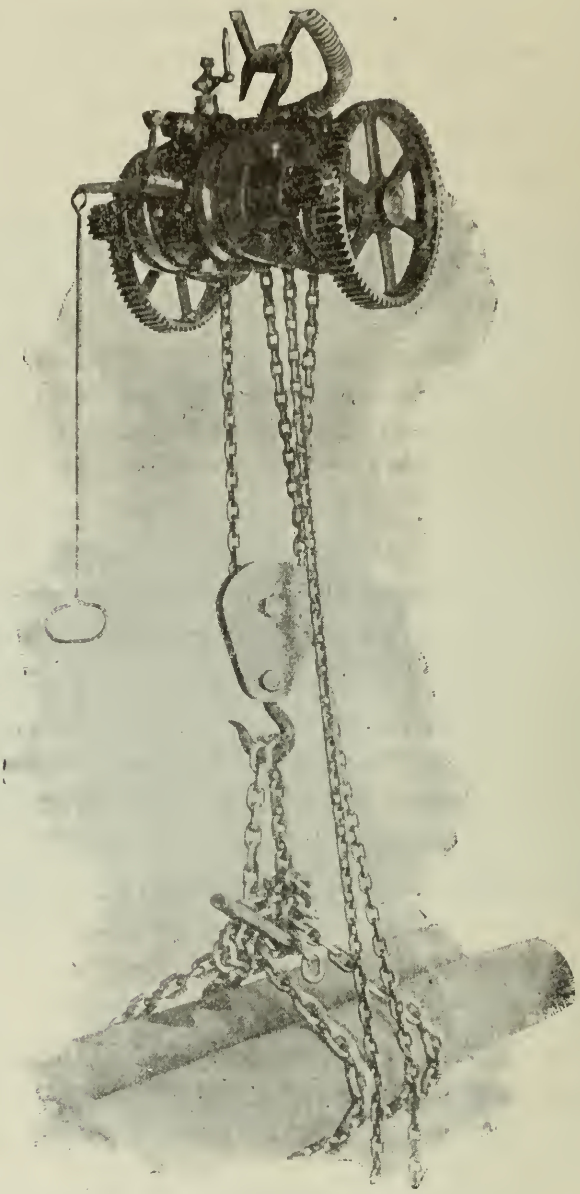


FIG. 2.—Pneumatic motor hoist.

The air-lift system for wells, consists of an air compressor, an air receiver to equalize the flow of air to the well and the piping in the well. The compressor is located in the engine room, where it is always under the eyes of the

FIG. 3.—Car-wheel hoist.

FIG. 5.—Car-lifting jack.

engineer, and as compressed air can be conveyed a considerable distance without loss, the well may be far away. The method of piping a well differs, according to its general conditions and the quantity of water to be pumped. No two wells are alike, and, consequently, the method of piping,

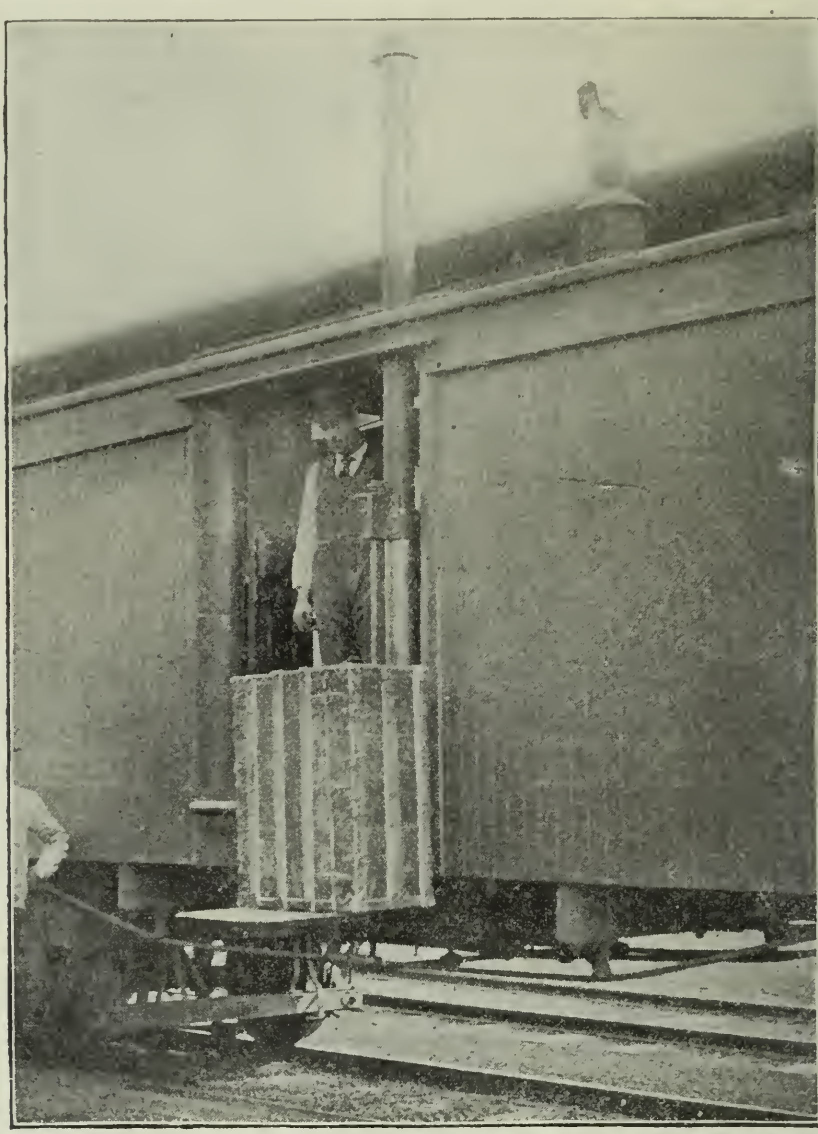


FIG. 4.—Baggage hoist.

which might be applied to one, would be unsuited to another.

In the accompanying illustration the method of piping consists of using the well casing as the water discharge pipe and simply putting a small air pipe down in the well,

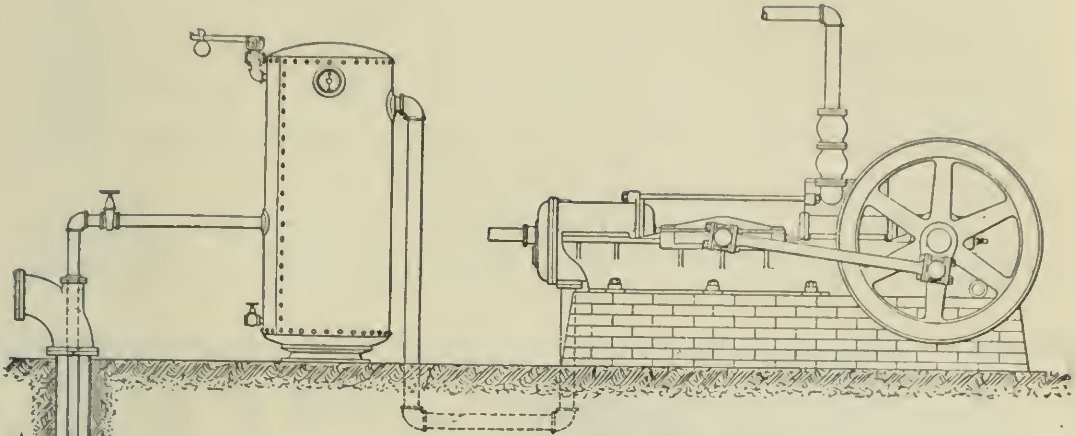


FIG. 7.—Air lift-pump.

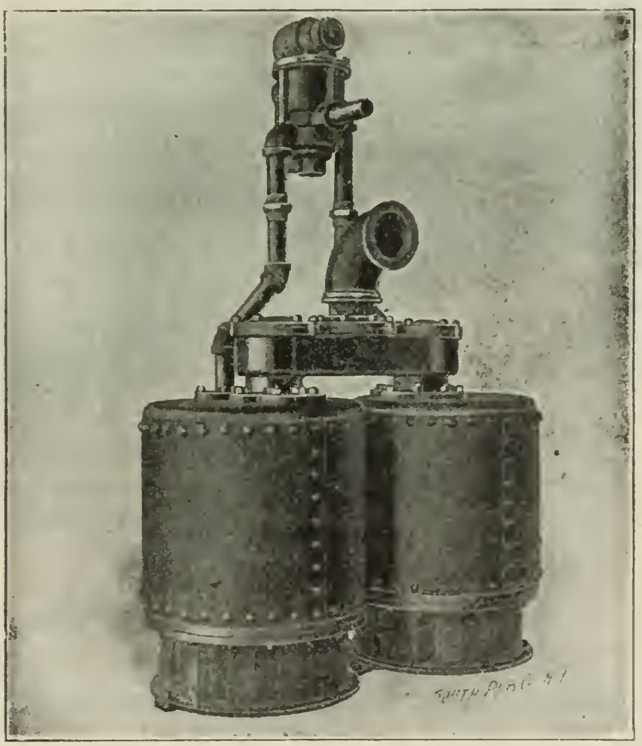


FIG. 6.—Displacement pump.

with a special device attached at the bottom through which the air escapes. Another method consists of placing the air and water pipes alongside of one another in the well, connecting them at the bottom with an end piece. A third method places the water discharge pipe into the well, the air passing down through the annular space between the well casing and the water pipe (*Fig. 7*).

Pneumatic Traction.—Traction is an important application of compressed air in a direction which is just now

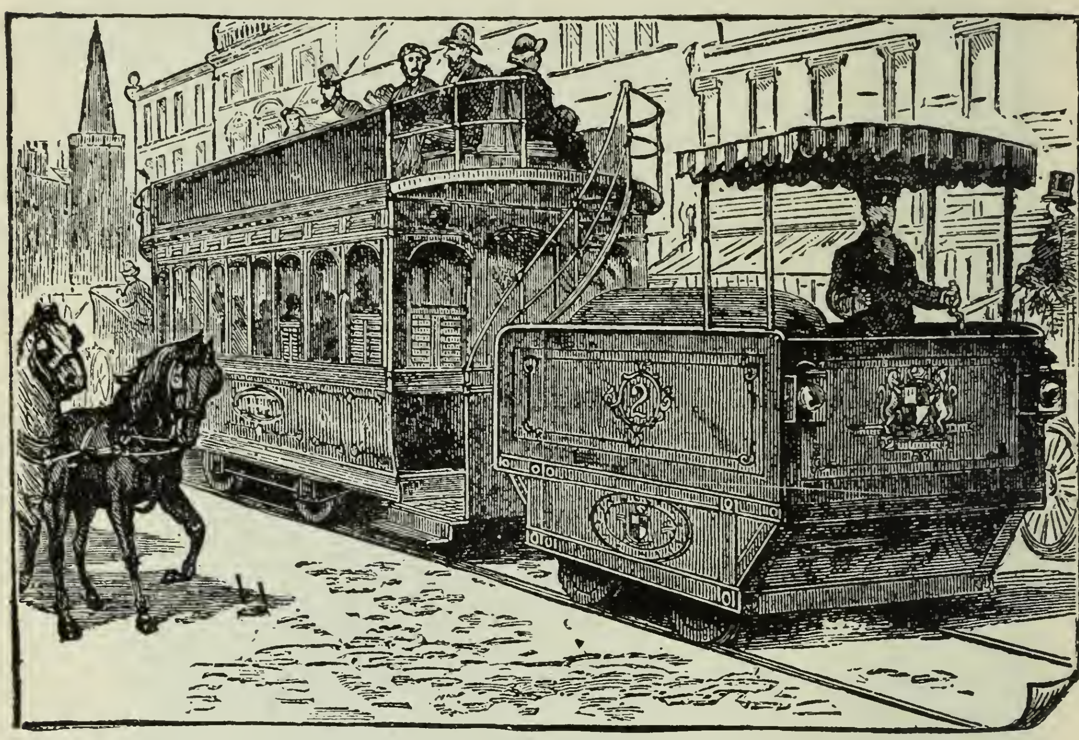


FIG. 8.—Trial of the Beaumont compressed-air motor at Woolwich Arsenal, England.

very promising. It is too broad a subject to be discussed in detail here, but I illustrate in the following the several prominent systems which have been put into practical operation. *Figs. 8* to *12*, inclusive.

In connection with this subject I can do justice to pneumatic traction in no better way than to attach herewith a reliable paper written by Mr. Edward E. Pettee, on the cost of operating the Hardie cars in New York City. The Hoadley-Knight system, which is in many respects similar

to the Hardie, and perhaps an improvement on it, is now being installed under the auspices of the Metropolitan Traction Company in New York on the Twenty-eighth and Twenty-ninth streets cross-town lines. It is hoped and believed that one year hence we will be able to present some facts of value in connection with this modern pneumatic street car installation.

Cost of Operating Air Cars in New York City.—It seems especially pertinent at this time to publish a statement of the actual operation and operating expenses of the American Air Power Company's cars that have per-

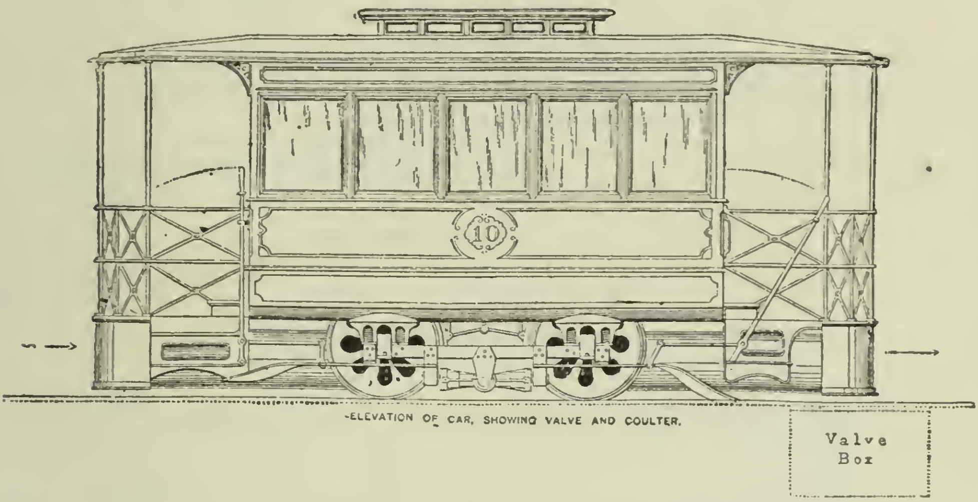


FIG. 9.—The Hughes and Lancaster system.

formed a regular commercial service on the One-hundred-and-twenty-fifth Street line of the Third Avenue R. R. in New York City, since the 3d of August, 1896, with a success unparalleled in the history of mechanical traction.

The period elapsed covers the extreme ranges of temperature experienced in this locality, and fortunately also two snow storms of more than ordinary severity, so that the seven months' continuous duty on which the following statement is based will meet the conditions incident to any street railway service.

The One-hundred-and-twenty-fifth Street line of the Third Avenue Railroad extends across town from the North River

to the Harlem River, the length of the tracks being 10,854 feet, making the round trip 4·11 miles, over which cable cars are operated at intervals of two and a half minutes. Air cars were substituted for two of these cable cars, the schedule calling for nineteen round trips each, or 79·09

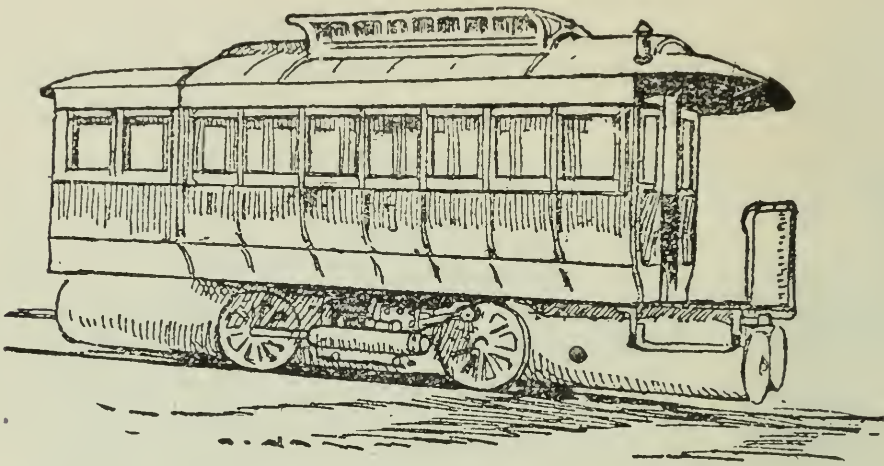


FIG. 10.—The Jarvis system.

FIG. 11.—The Mekarski system at Toledo, O.

miles per car; for a daily service of 156·18 miles, besides 1·14 miles of switching to and from the car house and street tracks, making the total distance covered daily 157·32 miles. Each car runs from 12·50 to 16·67 miles on a single charge of air.

The switching referred to is unavoidable in operating this service owing to the arrangement of the car-house in relation to the street tracks, it being some distance from the terminal of the road.

During a portion of the time, only single service was performed, as at present, so that the total average mileage per day from August 3d to March 3d, was 125·16 miles, and the total distance covered, 23,030·5 miles; and the total number of passengers carried, 137,386. The cars have operated every week-day, but are not run Sundays.

[*To be continued.*]

ELECTRICAL SECTION.

Stated Meeting, May 23, 1899.

A NEW PRIMARY BATTERY.

(THE HARRISON CELL.)

By J. D. Darling.

Although it was in 1793 that Volta discovered that when two discs of metal—one zinc and the other copper—were brought in close contact the zinc became charged with positive and the copper with negative electricity, it was not until 1799 that he constructed his famous primary cell, and it is now proposed to hold an exhibition at Como, Italy, his birthplace, from May to November of the present year, to celebrate the discovery a century ago of chemical electricity.

Few discoveries are more deserving of commemoration, as, previous to his discovery, the static machine was the only source of electricity the investigator had at his command. Volta's cell furnished the first practical source of electrical energy, and in a form that enabled experiments to be made which culminated in that of Faraday—the base of all our present electrical development.

I now wish to call your attention to the latest form of voltaic cell, which has been brought to perfection during

this centennial year, and in which it has been aimed to embody as many as possible of the desirable qualities that the experience of the past 100 years has shown to be necessary in a good voltaic cell. Ever since Volta pointed the way, efforts have been made to devise a perfect form of voltaic cell, but so far unsuccessfully; galvanic polarization and local action are the principal difficulties that beset the path of the inventor of primary cells.

As I will have occasion to refer repeatedly to polarization and local action in describing how these difficulties were overcome in the cell under consideration, I will here give the definition of these two terms as given by Park Benjamin.

"Polarization is a condition due to the formation of a body, most commonly hydrogen, by electro-chemical decomposition upon the negative electrode, whereby a current in opposite direction to the normal current of a cell is produced, and through which the normal current may be greatly weakened."

"Local action is chemical action occurring within the cell, and is caused by the innumerable small currents which circulate between portions of the same electrode."

A great variety of chemical substances have been used as depolarizers, and even mechanical devices to utilize the oxygen of the atmosphere have been tried. The substances have usually been such as will readily give up oxygen to combine with the hydrogen to form water, and may be either liquids or solids. An objection to liquid depolarizers, besides that of having two liquids in the same cell with the accompanying porous cup or other device to keep them separated, is that but a small percentage of the total depolarizer present in the cell is available for useful work, as there is generally a large amount of chemical energy left in the solution after it is too weak for satisfactory work.

Solid depolarizers are preferable to liquid ones, for with solid depolarizers one liquid only is required in the cell, and porous cups can be dispensed with, and the efficiency, or amount available for useful work, is also higher than is the case with liquid depolarizers.

The following table gives the E.M.F. of various cells in which a few of the most commonly used depolarizers—liquid and solid—are used, zinc being the positive element in each case :

Liquid Depolarizers.	Name of Cell.	Volts.
Copper Sulphate,	Daniel,	1·079
Potassium Chlorate,	Salleron-Renoux,	1·600
Nitric Acid,	Bunsen,	1·900
Potassium-Bichromate,	Poggendorff,	2·140
Cupric Oxide,	Lalande-Chaperon,	0·98
Silver Chloride,	De la Rue,	1·03
Manganese Peroxide,	Leclanche,	1·40
Mercurous Sulphate,	Mari-Davey,	1·412
Lead Peroxide,	Harrison,	2·45

It is evident that the cell in which lead peroxide is the depolarizer has by far the highest E.M.F. This new cell, known as the "Harrison" Primary Cell, No. 1, is the cell that I propose to describe in this paper. It is an open circuit primary cell, having a positive element of amalgamated zinc and a negative element of hard lead surrounded by a mass of specially prepared lead peroxide (PbO_2). The electrolyte is dilute sulphuric acid, 1 part of acid to 6 parts of water. The E.M.F. of the cell is 2·40 — 2·50 volts, the average being 2·45. The internal resistance averages ·15 ohm, therefore on short circuit the current is about 16 ampères. The negative element is in the form of a round stick, about 4 inches long by 1⅛ inches in diameter. It is made by compressing in a special machine a mass of lead peroxide around a central conductor of hard lead that has previously been treated in a way that prevents sulphating. This conductor is provided at one end with a copper screw that passes through the cover of the jar and is held in place by a binding post.

It is not claimed that the use of the lead peroxide for the negative element in this cell is new, for Benjamin says in his book, "The Voltaic Cell," page 228 : "In 1843 Wheatstone observed that by covering the negative electrode of a cell with a body of peroxide of lead or peroxide of manganese the E.M.F. of a cell could be greatly augmented. De la Rue reached the same conclusion at about the same period." Since then numerous inventors have tried to make a

practical cell, using lead peroxide surrounding a conductor as a negative element, but the difficulty of making a peroxide that would hold together, and not disintegrate when used, has never been overcome until recently.

This seemingly insurmountable difficulty has been practically overcome in the Harrison cell after several years of experimenting. Every kind of binding material that offered any hope of success was tried, and failed, and even coating the sticks after they were made with different cements was tried, and failed. Several times it was thought that success had been achieved, as occasionally sticks would last for

FIG. 1.—Harrison cell, No. 1.

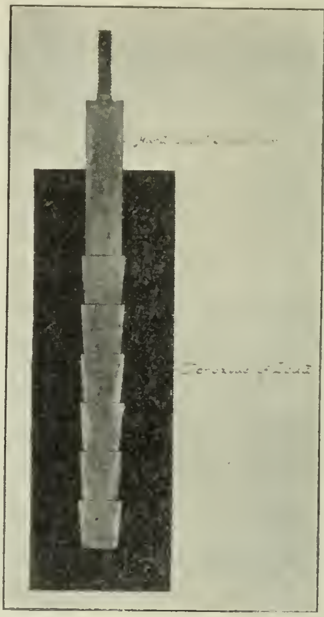


FIG. 2.—Negative element of No. 1 cell.

months without cracking or falling to pieces. Success was ultimately attained only after the trouble had been traced to its source, and special means and processes devised to prevent it.

The process of manufacture is now as follows:

The lead peroxide is prepared electrolytically, and when finished is almost chemically pure PbO_2. Certain precautions have to be observed to insure success. The neglect of any one of them gives us a peroxide that, when made into a stick, will crumble to pieces when put into the elec-

trolyte. The proper amount of finished peroxide is then compressed around the conductor in a very ingenious machine, especially designed for the purpose, and which is worked by compressed air. The finished sticks are allowed to dry for a week or more before being made up; they are then extremely hard, and stand handling and shipment very well.

I will now proceed to describe the positive element of the cell, which also possesses some new features. At first glance it appears to be only a short rod of zinc, 1⅝ inches long by 1 inch in diameter, with a short conducting copper wire attached to it, but, as dilute sulphuric acid is the electrolyte used in the cell, it is plain that zinc alone would not last long, and a closer examination will show that means have been taken to keep it amalgamated. It is well known that if the zinc element in a primary cell is kept well amalgamated there is little or no local action. Kemp, of Edinburgh, was the first to point this out, in 1828, and although it would appear to be a simple matter to keep the zinc amalgamated, in reality it is not, for on account of the high specific gravity of mercury it has a constant tendency to separate from the zinc, thus leaving the zinc open to attack by the acid. To overcome this tendency the zinc element in the Harrison cell is cast in the form of a cup, and has a stout copper wire, threaded at one end for attaching the binding post embedded in it. In this zinc cup and around the copper wire enough melted zinc amalgam is poured to completely fill it. This amalgam, when cold, is perfectly solid, and no free mercury is visible. This is a most valuable feature, as there is no mercury to spill and be lost when shipping the cell. Yet it is not necessary to amalgamate the zinc when setting up the cell, as

FIG. 3.—Positive element of No. 1 cell.

the mercury that is in the element in the form of solid zinc amalgam is almost instantly available when it comes in contact with the exciting fluid.

What occurs when the cell is set up is as follows: Zinc amalgam is electro-positive to pure zinc, the difference in potential being 0·05 volt; therefore, when the zinc element I have described is placed in dilute acid, the first action takes place on the surface of the zinc amalgam. The zinc of the amalgam is dissolved and a minute quantity of the mercury is liberated; this in a very short time spreads itself over the surface of the element and, as there is then nothing but zinc amalgam exposed to the acid, all action ceases.

The zinc element in the Harrison cell is, therefore, self-amalgamating, for it retains this property of liberating just the necessary amount of mercury needed to the end of its life. Tests have shown that the local action is very slight and that the amount of zinc dissolved bears a close relation to the amount of energy obtained, providing the sulphuric acid used is pure. If impure acid has been used in setting up the cell, local action will occur on the zinc. The reason for this is that the zinc is highly electro-positive in dilute sulphuric acid and will precipitate on itself all other metals lower in the electrolytic scale, or less positive, that may happen to be in the acid used in setting up the cell.

If the metals so precipitated readily amalgamate—copper, for instance—no harm will ensue, for they will combine with the amalgamated zinc and no local pair will be formed. But if, as is usually the case, the metallic impurities present in the acid are arsenic, selenium or iron, local action is certain to be set up, for they will be precipitated on the zinc and, as under the conditions they will not amalgamate, a multitude of local pairs are formed on the surface of the zinc element and it is rapidly consumed.

As sulphuric acid manufactured from iron or copper pyrites always contains more or less arsenic and selenium, such acid should never be used in the Harrison cell except the following precautions are strictly observed. If there is a doubt about the purity of the acid, proceed as follows: set up the cell as per directions and allow it to stand for

forty-eight hours. If the acid is not pure, local action will have been set up on the zinc and gas bubbles will be seen to be rising steadily instead of adhering to the zinc. To stop the action and prevent its return, take the zinc out and scrub it off thoroughly with a stiff brush in running water. This treatment will remove the precipitated impurities from the surface of the zinc that were causing the trouble, and as there are no more left in the solution, the zinc can be replaced again and there will be no further local action.

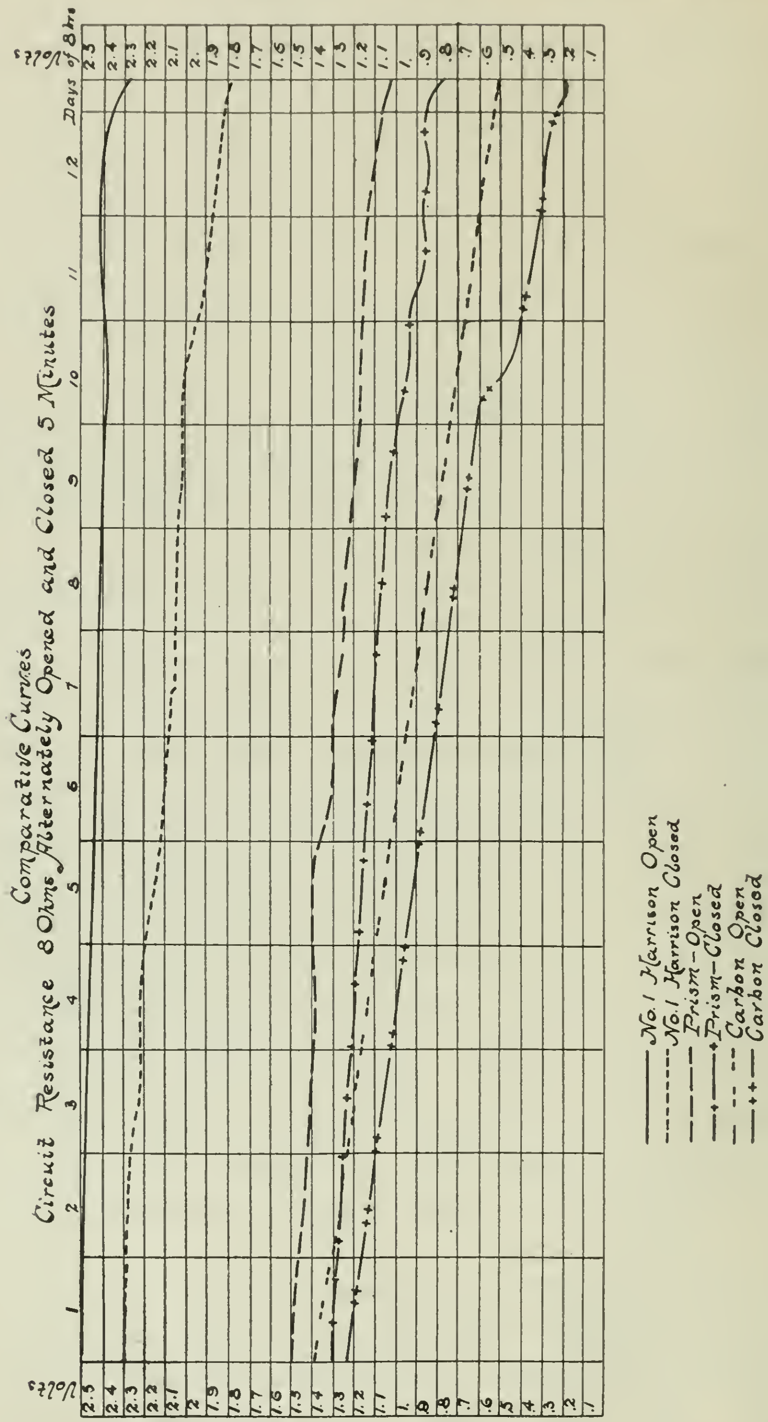
But it is much the better plan to use only pure 66° Baumé sulphuric acid in the Harrison cell, and if that is done there is practically no local action.

When there is an objection to the use of liquid sulphuric acid, a substitute for it in the bisulphates of potash or soda in solution can be used with almost equally good effect, providing the bisulphate used is pure.

I will conclude by calling your attention to the mechanical features of the cell and what it will do. As you may see, it is of neat and attractive appearance and of small size, being only 6 inches high over all, by 3 inches square. Owing to its shape, a large number occupy but a small space. The renewal of the elements is easily performed by unscrewing the binding posts, removing the exhausted elements and inserting new ones. The jar is graduated and properly marked so that no mistake can be made in putting in the right amount of acid and water when setting up the cell, and as dilute sulphuric acid is the electrolyte there are no salts to creep and corrode the connections. Primarily it is intended for open circuit work, where only one-quarter of an ampère or less of current is required; but it can also be used on light, or what may be called semi-closed circuit work, and any desired current can be obtained by putting cells in multiple.

The cell, on ordinary household work, such as bell-ringing or gas-lighting, will last for at least one year without attention, and then, by changing the acid, it will last for some time longer before it is necessary to change the peroxide stick for a new one. The zinc generally lasts as long as two peroxide sticks, but, of course, the life of the

cell depends upon the amount of work it is called upon to do. If, through defective wiring or any other cause, it is



short-circuited, or, as it is called, "grounded," its life will be shortened, as would be the case with any other primary cell.

The curves herewith shown were obtained by putting on the same resistance a Harrison cell and two of the ordinary sal-ammoniac cells, one having peroxide of manganese for a depolarizer and the other being a plain carbon cell. The circuits had each a resistance of 8 ohms, and they were opened and closed every five minutes by clockwork for twelve days of eight hours each. At the beginning of tests the E.M.F. on open circuit of each cell was: Harrison, 2·5 volts; sal-ammoniac cell (depolarizing), 1·5 volts; plain carbon cell, 1·4 volts. At the finish the E.M.F. on closed circuit was: Harrison cell, 1·8 volts; sal-ammoniac (depolarizing), ·8 volt; plain carbon cell, ·2 volt. This shows that the Harrison cell had at the finish of the test a higher E.M.F. on closed circuit than the best of the sal-ammoniac cells had at the beginning on open circuit by ·3 volt, and it should not be forgotten that the current from the Harrison cell had been at least double that of the other cells during the test.

I would now call your attention to another form of cell—what is known as the "Harrison Cell, No. 3." This cell has also lead peroxide and amalgamated zinc for its elements. It has been especially designed for heavy closed-circuit work. Its E.M.F., when new, is 2·7 volts, and its life is 300 ampère hours, on a slow rate of discharge.

In this cell the negative conductor is outside the peroxide of lead, and is in the shape of a perforated basket or grid, divided internally into four equal spaces by lateral walls, and supported by a central rod passing through the cover of the jar and forming the positive terminal of the cell. By this form of construction a large negative surface in close contact with the depolarizer is obtained. The entire element is of a very solid and substantial construction that is not easily injured in shipping, and, when exhausted, can be recharged and used over and over again.

The positive element is granulated zinc, lying on a copper grid on the bottom of the jar that has an insulated copper conductor passing up through the cover to form the negative terminal of the cell. To prevent local action, a quantity of mercury is placed in the bottom of the jar. which serves to keep the zinc constantly amalgamated.

Three advantages are secured by using granulated zinc. One is that because of the large surface of zinc exposed in close proximity to the negative element, the cell has a very low internal resistance and a consequently high ampèrage. Another is the ease with which the zinc can be replenished; and, thirdly, the economy obtained in the consumption of zinc. All the zinc put into the cell is used. There are no pieces left to be thrown on the scrap heap, as is the case with cells having vertical plates of zinc. Of course, there is the same need in this cell as in the No. 1 to use pure sulphuric acid, or a solution of pure bisulphate, and the same

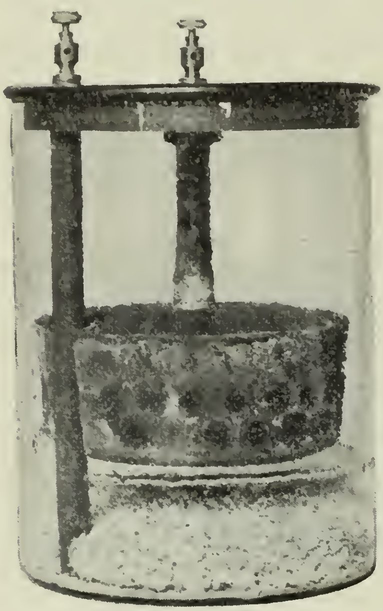


FIG. 5.—Harrison cell, No. 3.

FIG. 6.—Negative element of No. 3 cell.

directions apply for stopping local action caused by using impure acid.

Its high E.M.F., large current, freedom from local action and the ease with which renewals can be made give this new cell distinct advantages over all other forms of what are known as closed-circuit cells. It takes a battery of three copper oxide cells coupled in series to give the voltage of one No. 3 Harrison cell. Manufacturers and users of gas and gasoline engines have long felt the need of a high-voltage primary cell to operate the spark coil attached to their

engines, and I believe they will find what they have been looking for in this new cell. Physicians and dentists will also find it well adapted to their needs, and it can be used for operating coils in X-ray work, for telephones and phonographs, as well as for running small motors and fans.

Where small storage batteries are now used this new cell will be found more convenient, for, besides having a higher E.M.F., there is not the need to send away the whole cell to have it recharged; with an extra negative element and a supply of acid and zinc, the cell can be kept running continuously with but little trouble; or, if desired, and a current is at hand, it can be used as a secondary cell.

CHEMICAL SECTION.

Stated Meeting, held December 6, 1898.

REACTION VELOCITY.

By Dr. Robt. Hart Bradbury,
Member of the Institute.

(*Concluded from vol. cxlvii, p. 474.*)

In closing this brief exposition of the formulary side of our subject, it is interesting to note the extreme simplicity of the mechanism of chemical changes. Trimolecular reactions are extremely uncommon and reactions of a higher order than three are unknown at present. Now, the pages of every text-book bristle with reactions which, in terms of the molecular theory, require the meeting of many molecules. Take, for instance, the familiar

$$3Sb_2S_3 + 28HNO_3 = 3Sb_2O_5 + 9H_2SO_4 + 28NO + 5H_2O.$$

Undoubtedly such expressions describe correctly the quantitative transformations which have taken place, but as regards the mechanism of the change itself, the impression they produce is utterly false. For the present, it seems best to consider that the chemical equation describes the

result of a complex of changes which have occurred consecutively. For instance, in the decomposition of arsine,

$$4AsH_3 = As_4 + 6H_2,$$

the first event is simply

$$AsH_3 = As + 3H,$$

after which the arsenic and the hydrogen atoms are at once grouped into molecules As_4 and H_2.

We next proceed to consider disturbing influences which affect the course of a reaction and prevent the law of mass-action from finding clear expression.

The progress of chemical changes is profoundly affected by a great variety of circumstances which we should be inclined to regard, *a priori*, as entirely indifferent. In the case of gases, the character of the vessel walls; in the case of liquids, the solvent; in all cases the presence of various substances, which take no part in the change, are conditions which have enormous effect on the speed of transformation.

Starting with the simpler physical transformations, we may consider first the case of an evaporating liquid. Here the final state of things for any temperature is, neglecting gravity, a uniform vapor phase in equilibrium with the liquid. This requires an actual transportation of the substance through space, which is slowly brought about by diffusion.*

If a special structure, *e. g.*, a crystal, results from the change, production of this structure will require time, and this will influence the speed of transformation. In the melting of a solid, the liquid which results is structureless; hence, the velocity of change is simply proportional to the heat supply, and it is impossible to heat a solid above its melting-point.

In the reverse change, the solidification of the liquid, the product is crystalline, and the arrangement requires time

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* Van't Hoff, "Vorlesungen," p. 202. His discussion of catalytic action and allied topics is excellent, and I am indebted to it for several facts and suggestions.

to progress and, more especially, unless some of the same solid phase is added, time to begin.

Hence the phenomena of supersaturation and supercooling.

The influence of the vessel walls is most marked in the cases of gases, because the proportion of exposed surface to the total mass of the system is immensely greater than in liquid systems, and because of the greater rapidity of diffusion. The classical researches of V. Meyer, Krause and Askenasy in this field have failed to reveal anything beyond the magnitude of the influence and the perfect irregularity of the phenomena. The particular change investigated was the combination of hydrogen and oxygen. The stochiometric quantities were exposed to constant temperatures in small glass spheres. In different spheres of the same size, prepared in the same way and exposed to the same temperature, the speed of change is enormously different. The action of the hot-water vapor upon the glass changes the character of the surface, and this exerts an influence upon the transformation, which is sometimes accelerating and sometimes retarding. Etching the interior surface of the spheres by means of hydrofluoric acid yielded similar results. The speed of change was greatly increased by coating the interior of the spheres with silver, copper, platinum or palladium, but different spheres coated as nearly as possible in the same way, gave enormously different velocities. Van't Hoff* found that the speed of the polymerization of cyanic acid was increased by increase in surface of the vessel and by the separation of the cyamelide on the vessel walls during the change, and decreased by the alteration of the glass surface. On the other hand, in the decomposition of arsine, the reaction only becomes regular and follows the logarithmic formula when the vessel walls are fairly well coated with arsenic.

The great influence of the vessel walls in gaseous systems makes it permissible, for the present, to suppose that the reaction occurs chiefly in the layer of gas in contact

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* *Studien zur Chemischen Dynamik*, p 45.

with the vessel, and that the reaction products are then diffused into the rest of the space. This statement applies only to reactions which proceed slowly and not to explosions, but it is precisely such changes which are suitable for investigation. The irregularities just discussed throw great difficulties in the way of research, and it is a natural consequence that reactions in gaseous systems which are susceptible of quantitative treatment are rare at present.

The beginning of a chemical change is usually irregular. According to the mass law all changes should begin with their maximum velocity and the speed should continuously decrease as exhibited in the equation

$$\frac{dx}{dt} = k(a - x)^n$$

Bunsen and Roscoe, in their study of the combination of hydrogen and chlorine, observed that the initial velocity was small; then followed a rapid rise to a maximum, from which it slowly decreased as the mass law requires. They considered the phenomenon general and called it photo-chemical induction. The state of things at the beginning of a chemical change has not received the attention it deserves, but it is not likely that Bunsen and Roscoe were correct in this assumption, though other similar cases are known. In the case of gaseous systems, the irregularities just alluded to prevent us from drawing valid inferences, and in liquid systems the facts can be explained by catalytic action of the reaction products, and by unavoidable slight rises in temperature. Certainly the supposition that the first portion of a chemical change is not described by the mass law is too violent to be made upon the present evidence.

In liquid systems the effect of the vessel walls is of no importance, but that of the medium in which the reacting substances are dissolved is enormous. The difference is, that while in gaseous systems the influence of the vessel walls introduces an indeterminable element into the problem and prevents the quantitative treatment, the influence of the solvent is constant, and exhibits itself simply in its effect upon the velocity constant k. We owe the most

extensive researches on this subject to Menschutkin. The velocity of combination of triethylamine and ethyl iodide

$$N(C_2H_5)_3 + C_2H_5I = N(C_2H_5)_4I$$

was investigated in a great variety of solvents. The temperature was 100°. The great variation in the velocity constants is sufficiently illustrated by the fact that, taking the speed in hexane ($k = \cdot 00018$) as unity, then the speed in acetone ($k = \cdot 0608$) is 338, that in acetophenone ($k = \cdot 1294$) is 720, in benzyl alcohol ($k = \cdot 133$) 740.

Carrara has investigated the combination of ethyl sulphide with methyl iodide to diethyl-methyl-sulphine-iodide

$$(C_2H_5)_2S + CH_3I = (C_2H_5)_2CH_3SI.$$

The temperature was 100°. Taking the speed in acetone $k = \cdot 00015$ as unity, that in benzyl alcohol is 40, in ethyl alcohol 100, and in methyl alcohol 620. The considerable difference between ethyl and methyl alcohol is interesting.

Little is known, as yet, regarding the connection between this influence and the other properties of the solvent. The velocity is much greater in aldehydes, esters, alcohols and oxygenated derivatives generally than it is in hydrocarbons and their halogen substitution products, but the decrease from acetophenone to acetone, for instance, shows that the speed does not always increase with the oxygen content. Nernst has pointed out* that in general the reaction velocity is greatest in those solvents which produce the greatest degree of ionisation in electrolytes and in which non-electrolytes have the smallest molecular weights. Very recently, Cohen,† acting upon a suggestion by Nernst,‡ has investigated the effect of the addition of an indifferent gas upon the velocity of decomposition of arsine. The results are particularly interesting, because they bear upon the question, whether a gaseous phase whose composition is capable of continuous variation should be regarded from the same

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* "Theoretical Chemistry," English Edition, p. 484.

† "*Zeitschrift für Phys. Chem.*," XXV, p. 483 (1898).

‡ "Theoretical Chemistry," English Edition, p. 484.

point of view as a liquid phase having the same property, that is, as a solution. The full discussion of this question lies quite outside the scope of the present paper, but the answer, so far as the study of the reaction velocity can furnish it, is negative. Cohen found that the addition of hydrogen and nitrogen in excess was without influence, and this stands in direct opposition to the behavior of liquid systems.

Catalytic action upon reaction velocity is distinct from the influence of the solvent in two respects: (1) the quantity of the active substance is small in comparison to the quantity of material changed by it, for instance, in the inversion of sugar by hydrogen ions the quantity of the latter relative to the quantity of sugar inverted may be made excessively small and the change still occur with a measurable speed; and (2) in a reversible reaction the catalyzing substance affects simply the speed with which the final state of things is attained, and is entirely without influence on the mass relations of the substances at the end of the change. This principle is easily deduced from the second law of heat. By making the opposite assumption that the catalytic substance does displace the equilibrium, we encounter a perpetuum mobile of the second kind. It is, of course, confirmed by the results of experiment. Lemoine, in his classical researches upon the decomposition of hydrogen iodide, found that the speed with which equilibrium was reached was very much increased by the presence of platinum black, but that the distribution of the substances when the equilibrium

$$2HI = I_2 + H_2$$

was reached was unaffected.

It is desirable that this fact, that the active substance in a reversible catalytic change has no effect on the final equilibrium, should become more generally known, for the opposite assumption is not infrequent in chemical literature.*

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* Compare the work of Schiff on the equilibrium between the keto- and enol- forms of the esters of the ketonic acids, *Berichte*, XXXI, pp. 205, 602, 1304.

A host of facts regarding the catalytic influence of various substances on chemical changes is known, and the differential equations necessary for dealing with the data quantitatively have very recently been supplied by Ostwald.* Since the facts and the equations have not yet been brought into relation, all that we can do at present is to state the general character of the phenomena and to attend to some of the more remarkable of the facts.

Catalysis is best defined as the acceleration or retardation of a chemical process by a substance which itself remains unaltered and whose quantity bears no relation to the total amount of substance transformed. Cases of this kind of action, *e. g.*, the action of platinum in promoting the combination of hydrogen and oxygen and the decomposition of hydrogen peroxide, the inverting influence of hydrogen ions on sugar, have long been familiar. The recent discovery by Buchner of the unorganized ferment, zymase, of the yeast plant ranges the ordinary alcoholic fermentation under the head of catalytic processes. Water vapor appears to play a peculiarly important role in facilitating chemical changes catalytically. Quite a large number of qualitative facts showing this have been brought to light of late, especially by Dixon and by Baker, who have shown that some of the most familiar and energetic reactions of inorganic chemistry fail to take place, or, better, take place so slowly as to escape observation when the reacting substances are completely dry. In perfectly dry oxygen phosphorus and carbon burn only with the greatest difficulty, burning potassium is extinguished,† carbon monoxide does not burn and does not explode when electric sparks are passed, and nitric oxide mixes inertly without any production of nitrogen peroxide. Dry chlorine is without action upon copper and sodium and explodes with difficulty when mixed with an equal volume of dry hydrogen and exposed to the light of burning magnesium. Dry hydro-

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* "*Lehrbuch*," Vol. II, Part II, p. 262.

† Roscoe and Schorlemmer, Vol. II, p. 228 (1898). The statement has recently been called into question.

chloric acid gas mixes with dry ammonia without the production of any ammonium chloride, and conversely perfectly dry ammonium chloride does not dissociate when vaporized. In cases like this it is best to assume, for the present, that the function of the water is to increase the velocity of the change and that in its absence the process occurs so slowly as to escape detection. It may be added that absolutely dry hydrogen sulphide is without action upon metallic salts and that dry hydrochloric acid does not appear to affect marble.

THE EFFECT OF VARIATION OF TEMPERATURE.

In all cases thus far investigated reaction velocity is enormously accelerated with rising temperature. It was found by Trevor* that the inversion of sugar proceeds four thousand times as rapidly at 100° as at 25°, and other reactions exhibit a similar behavior. Cooling to very low temperatures diminishes the reaction velocity until the change apparently does not occur at all. The most interesting work in this direction is due to Raoul Pictet.† His low temperatures were obtained by means of boiling nitrous oxide or boiling liquid air. The most remarkable result is that at temperatures in the neighborhood of — 150° substances, which ordinarily react energetically, are quite inert. Mixtures of solid sulphuric acid, with caustic soda or caustic potash can be compressed strongly at — 125° without the slightest evidence of change; if the mixture is allowed gradually to warm, then at — 80°, in the case of the soda, and at — 90° with potash there occurs a reaction, and the tube containing the mass is broken by the sudden evolution of heat. Sulphuric acid and ammonia, and hydrochloric acid and ammonia seem quite without action on each other at — 70°. Acids do not affect blue litmus, and alkalies produce no change in the color of red litmus and develop no tint in alcoholic phenolphthalein. At these temperatures the three ordinary acids do not appear to

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* *Zeit. Phys. Chem.*, 10, 321 (1892).

† *Comptes Rendus*, 115, p. 814 (1892).

affect carbonates; no evolution of carbon dioxide was observed. Alcoholic barium chloride remains clear when mixed with sulphuric acid, and the same is true of silver nitrate and hydrochloric acid. Sodium thrown into hydrochloric acid swam about without any evolution of hydrogen. A later investigation of this particular reaction has shown* that the hydrochloric acid contains sodium after the experiment, and accordingly we have here simply a case of very small velocity of change and not of equilibrium. Whether we are to apply this explanation to all the changes, and consider simply that with cooling the reaction velocity becomes very small, or whether we are to consider that there may be "false equilibrium" at low temperatures without any change whatever is uncertain. Nernst† and Ostwald‡ appeal to the law of continuity and to many facts in support of the first assumption. Duhem § has developed with great mathematical ability the second. This topic belongs, however, to the subject of chemical equilibrium.

SUPPLEMENTARY.

Very recently a reaction of the fourth order—a tetramolecular reaction—has appeared.||

The reduction of bromic acid by hydrobromic acid,

$$HBrO_3 + 5HBr = 3H_2O + 3Br_2,$$

is accurately described by the equation,

$$\frac{dx}{dt} = R(A - x)^4,$$

and the values of k calculated from the integrated form of the equation are very satisfactory. In the presence of excess of sulphuric acid the same reaction becomes bimolecular. It had been previously shown that the action of haloid acids upon their corresponding oxygen acids possessed a complex

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* Dorn aud Völlmer, *Wiedemann's Ann.*, 60, 848.

† "Theoret. Chem.," Eng. Edition, p. 573.

‡ "*Lehrbuch*," Vol. II, Part II, p. 287.

§ *Traité de Mécanique Chimique*, Vol. I, p. 219.

|| Judson and Walker, *Journ. Chem. Soc.*, 73, 410 (1898).

mechanism and was probably of the fourth order, but this is the first tetramolecular reaction for which satisfactory velocity constants have been obtained.

Von Sigmond* has shown that the hydrolysis of maltose is monomolecular, and proceeds in general very similarly to the sugar inversion, except that the reaction is very much slower.

Price† has shown that the oxidation of potassium iodide by potassium persulphate,

$$2KI + K_2S_2O_8 = 2K_2SO_4 + I_2,$$

is bimolecular, and has made an interesting study of the influence of various metallic salts on the progress of the change.

The most remarkable result is that when two substances acting catalytically are present together, their influence is not necessarily additive, but that the catalytic action of one may be increased by the presence of the other. For instance, in this case, the influence of copper sulphate and iron sulphate together is more than twice as great as that calculated on the basis of a simple additive relation. So far as I am aware, this is the first instance of this kind to appear.

CENTRAL MANUAL TRAINING SCHOOL,
PHILADELPHIA, January 7, 1899.

BOOK NOTICES.

Premiers Principes d'Électricité Industrielle. Piles, accumulateurs, dynamos, transformateurs. Par Paul Janet. (Ouvrage couronné par l'Académie des Sciences.) 3ième Edition, entièrement refondue. Paris: Gauthier-Villars. 1899.

The present edition of this capital work, well known and appreciated by French readers, has been considerably enlarged and revised.

The subject of accumulators has been brought up to date, with especial reference to the application of these to electric traction, which appears to have progressed much further in France than in this country. The chapters relating to dynamos, alternators and transformers have also been considerably enlarged and rewritten to conform to the most recent practice. W.

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* *Zeit. Phys. Chem.*, 37, 385 (1898).

† *Zeit. Phys. Chem.*, 37, 474 (1898).

A Treatise on Photographic Optics. By R. S. Cole, M.A., etc. Illustrated. New York: D. Van Nostrand Co. 1899. Price, $2.50.

This volume should prove a useful contribution to an important branch of applied optics, in which the literature is by no means as voluminous or satisfactory as it should be considering the universal extension of the practice of the art to which it relates.

The treatment of the subject is necessarily mathematical, but the author has endeavored to make his treatment as intelligible as possible by worked numerical examples. The chapter headings embrace the following subjects, viz.: Light, elementary theory of lenses; aberration, correction of aberration and the design of lenses; lens testing, exposure, stops and shutters; enlargement, reduction, depth of focus and halation. W.

Portland Cement, its manufacture and use. By Charles D. Jameson, M. Am. Soc. C. E., etc. New York: D. Van Nostrand Co. 1898. Price, $1.50.

This volume treats of the making, testing and using of Portland cement, and is described in the preface to be the outgrowth of a short course of lectures delivered by the author to the students of engineering in the University of Iowa.

The several chapters treat of the selection of the raw materials, their preliminary treatment, the leading types of kilns used, reduction of the clinker to powder, etc., the requirements for testing as set forth in the various standard specifications, the methods to be followed in testing and the different forms of mechanical devices employed in making the tests, the comparative value of different cements, the uses of Portland cement as a material for construction, the proper methods of manipulating it, and estimates of quantities and cost.

The volume is well illustrated and the subject is treated concisely and clearly. W.

American Newspaper Annual. (Nineteenth edition.) Philadelphia: N. W. Ayer & Son. 1899. Price, $5.

The great experience of the publishers of this annual enables them to add to the value of each succeeding volume by the introduction of new data of use to business men and others for whom the work is designed. The present edition forms an imposing volume of several thousand pages, and it is safe to say that, in point of accuracy, comprehensiveness and excellence of classification, it is all that could be reasonably desired. W.

International Railway Commission. Vol. I, Part 1. A condensed report of the transactions of the Commission and of the surveys and explorations of its engineers in Central and South America, 1891–1898. Washington. 1898.

This volume gives a general summary of the work of the Intercontinental Railway Commission, constituted for the purpose of realizing the Intercontinental Railway to connect the northern and southern portions of the American Continent. It contains an historical sketch of this ambitious project, together with a *résumé* of the legislation adopted by the Congress of the

United States, which resulted in the convocation of the International American Conference and the formation of Intercon'inental Railway Commissions. It contains, also, an outline of the work accomplished by the engineers of the Commission, which may be regarded as a preliminary survey, not definitive, but presented as a contribution from the technical branch of the Commission to determine the feasibility of constructing a trans-continental trunk line.

W.

Sanitary Engineering of Buildings.—By Wm. Paul Gerhard, C.E. Vol. I (with 103 illustrations and 6 plates). New York: William T. Comstock. 1899.

This work has been prepared by the author to take the place of his "Hints on the Drainage and Sewerage of Dwellings," the third edition of which was, some months ago, exhausted.

The material of the earlier work, in revised form, constitutes the first five chapters of the present greatly enlarged work, which embraces twelve chapter headings. The author is a voluminous contributor to the technical journals, and has culled freely from these contributions for the material embraced in Chapters VI to XII; but this has been revised and expanded, and its value considerably enhanced by the introduction of new illustrations.

The present volume treats of defective plumbing and sewer gas, traps and systems of trapping, drainage and sewerage of buildings, plumbing fixtures, sewage removal and disposal, principles of scientific house drainage and sanitary plumbing, improved methods of house drainage, proper arrangement of water-closet and bath apartments, sanitation in factories and workshops, sanitary drainage of tenement houses, testing house drains and plumbing work, and simplified plumbing methods.

The arrangement of subjects appears to be excellent; and the method of treatment as thorough and reliable as we should anticipate from an engineer of the extensive professional experience of Mr. Gerhard.

A second volume, now in preparation, will treat of questions of water-supply, sanitary arrangements of suburban and country houses, sanitation of public buildings, etc., and the completed work should form a valuable reference book for the professions and trades interested in the subject. W.

La Bicyclette, sa Construction et sa Forme. Par C. Bourlet, Docteur ès Sciences, Membre du Comité technique du Touring-Club de France. Un Volume Grand in-8, 228 pp., et 264 figures. Paris: Librairie Gauthier-Villars. 1899. 4 francs, 50 c.

The author of this work, who is a distinguished contributor to the art to which it relates, has given us a very comprehensive treatise in the 225 pages comprised therein.

The volume opens with an interesting historical sketch, and which is followed in order by chapters treating of the construction and form of the machine, taking up successively the frame, the steering head, the bearings, the transmitting mechanism, speed-changing devices, wheels and tires, tricycles and "sociables," accessories.

A chapter is devoted to advice to wheelmen on the choice and care of the machine and accessories, and hygienic considerations. The concluding chapter is devoted to the theory of the bicycle. W.

The Elements of Physics. A college text-book. By Edward L. Nichols and Wm. S. Franklin. In three volumes. Vol. II, Electricity and Magnetism. New York: The Macmillan Company. 1896. Price, $1.50.

This work is well known to teachers of physics as a thoroughly trustworthy, up-to-date treatise on the subject, well arranged and adapted for its intended service. W.

Photographic Mosaics. An annual record of photographic progress. 1899. (Thirty-fifth year of publication.) New York: Edward L. Wilson; London: Dawborn & Ward.

The successive annual volumes of "Photographic Mosaics" lose nothing of their interest and value to the professional and amateur photographer. The present volume, the thirty fifth of the series, devotes 106 pages to a review of photographic progress during the previous year, which will be found convenient for reference by all who aspire to keep in touch with the current advances in the art, and the remaining 186 pages are devoted to contributions on a great variety of live subjects of interest to photographers, from well-known experts. This volume is as profusely and handsomely illustrated as usual. W.

PUBLICATIONS RECEIVED.

Acetylene Gas for Popular Lighting. Pan-American Acetylene Company, Buffalo, N. Y.

Maximum Stresses in Framed Bridges. By Wm. Cain. New York: D. Van Nostrand Co. 1897. New and revised, constituting No. 38 of the Van Nostrand Science Series. Price, 50 cents.

A Laboratory Course in Experimental Physics. By W. J. Loudon, B.A., and J. C. McLennan, B.A. New York and London: Macmillan & Co. Price, $1.90. From John Wanamaker, Philadelphia.

A Higher Industrial and Commercial Education as an Essential Condition of Our Future Material Prosperity. An address before the Society for the Promotion of Engineering Education. By J. B. Johnson, President of the Society. Delivered in Boston, Mass., August 18th, 1898. (Reprinted from the Society's Proceedings.)

Soft Coal Burning. By C. M. Higginson. (Fifth edition.) Chicago. 1898. A brief disquisition on the essential features of construction and operation of steam boilers to insure smokeless combustion with soft coals.

Franklin Institute.

[*Proceedings of the stated meeting held Wednesday, June 21, 1899.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, June 21, 1899.

MR. H. R. HEYL in the chair.

Present, 201 members and visitors.

Additions to membership since last report, 40.

Mr. B. S. Lyman, Chairman of the Committee on Library, made a brief report of the present condition and needs of the library.

Mr. T. B. Kinraide, of Jamaica Plain, Mass., described a new form of induction coil of great power which he had devised, and which he has applied with remarkable success to the study of the structural forms of electrical discharges with the aid of photography. The speaker described the apparatus and exhibited it in operation. He likewise showed a large number of photographic prints of these discharges, and numerous photographic plates of large size, with the aid of the lantern. The figures thus obtained and exhibited were of extraordinary beauty, and elicited unbounded admiration.

The subject was referred to the Committee on Science and the Arts.

Mr. W. J. Clarke, of New York, followed with an experimental exhibit of his apparatus for wireless telegraphy, with which a striking and successful demonstration was made. The speaker explained the underlying principles of this branch of the art of telegraphy, and gave a brief sketch of its development.

Referred to the Committee on Science and the Arts.

Mr. John Condon, of Philadelphia, described and exhibited in operation an improved form of acetylene gas generator of his invention.

Mr. W. N. Jennings exhibited, with the aid of the lantern, some photographs showing the progress made during the past month upon the buildings of the impending exposition, and gave a brief descriptive account of them.

The meeting passed a vote of thanks to the speakers of the evening and adjourned.

WM. H. WAHL, *Secretary.*

COMMITTEE ON SCIENCE AND THE ARTS.

[*Abstract of proceedings of the stated meeting held Wednesday, June 7, 1899.*]

The following reports were considered :

The Moskowitz System of Electric Car Lighting.—Held under rules for one month.

Protest of Mr. E. J. Moore against the Committee's report on his improvements in Moore's steam boiler.

The Committee voted to sustain the report and dismissed the protest.

Pneumatic Truck Cushion for Railway Cars.—Frederick S. Owen.

ABSTRACT.—The device consists of a corrugated steel tube, of suitable length for a car-spring, with steel heads brazed on the tube ends, one head having a plug with a valve on the point for closing the filling space in said head. The inventor's intention is to form a spring in this manner, and to use air pressure to sustain the load. (Drawings only submitted.)

The investigators are in doubt as to what such a spring would do without actual test of sufficient duration to determine the life of the metal, which they think would be short. Also, they know of no metal that could withstand the fatigue required of it by this service. [*Sub-Committee.*—Wm. Penn Evans, Chairman; J. J. De Kinder and Henry F. Colvin.]

The following reports passed second reading:

The Acid-Blast for Etching Metal Plates.—Louis Edward Levy, Philadelphia.

This report was referred back to the Sub-Committee on the representation of the applicant that a patent had just been issued to him, covering much broader ground than that which the Sub-Committee had had under consideration.

Plastic Bond for Electric Railways.—Thos. A. Edison and Harold P. Brown, New York.

ABSTRACT.—This invention is secured by U. S. letters-patent, No. 509,518, November 28, 1893, issued to Thos. A. Edison and H. P. Brown, and in substance is as follows:

The surfaces on the rails near the ends are bonded as well as the surfaces of contact of the bonding conductors—which may be either the fish-plates or appropriate copper conductors—will permit, and the contact is enhanced by the interposition between these surfaces of a plastic amalgam or alloy of mercury, with other metals, mainly copper.

This invention has been under investigation for several years, the investigators being of the opinion that the real value could only be determined by the test of time. The opinion is expressed that the success of this bond depends very largely on the care with which it is applied, but that with proper care in its installation it can be maintained in good condition, with periodical testing, at comparatively small cost. The Edward Longstreth Medal of Merit is awarded to the inventors. [*Sub-Committee.*—Geo. F. Stradling, Chairman; Thos. Spencer, Wm. C. L. Eglin, E. A. Scott.]

Internally-fired Water-tube Boiler.—Robert S. Kinney, Philadelphia.

ABSTRACT.—The invention is the subject of letters patent of the United States to applicant, No. 575,118, January 12, 1897.

The structural details of this boiler would be unintelligible without the aid of illustrations. This abstract, accordingly, will be restricted to the conclusions reached by the Committee, which are substantially as follows:

The Kinney boiler has several valuable features met with in other boilers, which may be enumerated as follows: A definite course for the feed-water, with provision for separating out the precipitable salts; a good arrangement and disposition of materials in the lining for the proper burning of s ft coals; a small number of made joints, which must be broken to clean the boiler; the absence of stays.

The apparatus is credited also with the following distinctive character-

istics: Small space for a given horse-power, large evaporation per square foot of heating surface.

The investigating committee, from the results of its tests, state that in economy this apparatus is as good as any boiler used at present, and that it possesses high evaporative power for a given space at low rates of combustion. The details are well worked out, and conform to the best present practice. A certificate of merit is awarded to the inventor. [*Sub-Committee.*—H. W. Spangler, Thos. P. Conard, Wm. Penn Evans, Arthur M. Greene, Jr.]

Electric Program Clock.—Frederick Frick, Waynesboro, Pa.

ABSTRACT.—The invention is patented to applicant by letters-patent of the United States, No. 535,948, March 19, 1895, and No. 551,375, December 17, 1895.

The purpose of the invention is the production of efficient mechanism by means of which certain predetermined signals may be automatically brought into action, by electrical devices, at times and places desired. This is useful, especially in schools, colleges and institutions, in announcing time for studies, recreation, rising, retiring, etc., and for analogous service in manufacturing and business establishments, where regularity is a necessity, according to a prearranged program.

The mechanism consists of a clock or timepiece of good construction for keeping correct time, and of a spring motor operating to revolve a disc of metal a portion of a turn at short intervals of time, the disc having a series of perforations arranged in concentric circles and in radial rows with pins fitting in certain spaces of the same, which make contact through a spring contact-piece, forming an electric current and ringing a bell or bells.

The mechanical details could not be explained without illustrations.

The report finds the meritorious features of this apparatus to consist: (1) in the relieving of the time-keeping mechanism of almost all labor, the lifting of the lever and the operation of the starting spring being all that is required of it; (2) the substitution of a flat disc of metal to carry the pins of the program-contacts, which are seen and inserted with great facility; and (3) the improved form of the calendar switch in which the pins are readily changed, and which are not in any electric circuit. These, the investigators believe, constitute an advance in the art.

Also, the investigators report the satisfactory operation of these clocks in actual service, one of them having been under the personal observation of one of the members of the Committee for four months, and to confirmatory evidence from a number of those having the apparatus in use. It relieves the head of the school or institution of annoyance in not having signals given promptly, with all the attendant confusion resulting from the want of a reliable signalling device.

The inventor is given the Edward Longstreth Medal of Merit in recognition of the merits of his program clock. [*Sub-Committee.*—J. Logan Fitts, Louis Breitinger, Hugo Bilgram, Wm. T. Lewis.]

The stated meeting of June 7th is the last prior to the summer recess. The Committee stands adjourned until the stated meeting of September 6th. W.

JOURNAL

OF THE

FRANKLIN INSTITUTE

OF THE STATE OF PENNSYLVANIA,

FOR THE PROMOTION OF THE MECHANIC ARTS.

VOL. CXLVIII, No. 2. 74TH YEAR. AUGUST, 1899

Physical and Astronomical Section.

Inaugural meeting, Friday, May 19, 1899.

THE RELATIONS OF PHYSICS AND ASTRONOMY TO THE DEVELOPMENT OF THE MECHANIC ARTS.

BY PROF. CLEVELAND ABBE.
U. S. Weather Bureau, Washington, D. C.

It is but four months since, on the 18th of January, you celebrated the seventy-fifth anniversary of the Franklin Institute. This is, therefore, an anniversary year, and it will not be long before January of the year 1906, when you will have an opportunity to celebrate the two hundredth anniversary of the birth of Benjamin Franklin, whose name is held in reverence and inscribed above your portals.

You now propose to inaugurate a new branch of activity for the Franklin Institute. Not long since you added the Mechanical and Engineering Section to those already existing, and you have now added a fifth, to be entitled "The Section on Astronomy and Physics." The organi-

zation of the Franklin Institute will, therefore, hereafter include, not merely a "Committee on Science and the Arts," and "Sections on Engineering and Mining and Metallurgy," but also special sections on important branches of science, such as astronomy, general physics, electricity and chemistry.

You have thus recognized the existence of certain relations between the advanced sciences and the practical arts. The Franklin Institute is devoted primarily to the promotion of the mechanic arts, but you have recognized that the sciences are so closely related to the mechanic arts that it is to your advantage to give them a distinct recognition in your organization.

I. THE MECHANIC ARTS CLOSELY RELATED TO PHYSICAL SCIENCES.

This inaugural meeting of your newest scientific section is, therefore, an appropriate occasion on which to consider with some detail the precise character of the relation between physics and the mechanic arts. I do not say astronomy and physics because that branch of astronomy which we shall consider is itself known as celestial physics. We have celestial and terrestrial and molecular physics, three branches of knowledge that are all included under the comprehensive term *physics*, or the science that treats of *force*. Ages ago man recognized only those forces in which large masses of matter are involved. He studied projectiles, falling bodies, the equilibrium of forces, the buoyancy of vessels, the motions of waves and tides and winds, and even the motions of the heavenly bodies. But now he has learned that all chemical phenomena have to do with the motions and equilibrium of molecules; that heat and light and electricity and the photographic or chemical action of light are but the motions of individual molecules of ponderable matter, and of the imponderable ether atoms that drive the material molecules hither and thither; that sound is but the motion of larger groups of molecules. Everywhere he is confronted by the laws of force.

If you strike a smart blow with a hammer upon the

head of a cold chisel and make a cut into a piece of soft iron, you are doing one of the simplest mechanical operations, and yet you are awakening a long list of reactions that invade every branch of physical science:

(1) The muscles respond to the eye and the will; the hammer moves with great acceleration and strikes straight and hard; the energy of the blow comes from the chemical transformations going on within the workman's body, suggesting problems that belong to the profoundest depths of biology.

(2) The stroke of the hammer calls forth a clear and cheerful sound from the head of the chisel—a musical ring with all its problems in acoustics.

(3) The hammer, the steel chisel, the soft iron and the chips become warm and hot under the repeated blows, suggesting problems in thermodynamics and the radiation and conduction of heat.

(4) The edge of the hard chisel becomes dull, but a deep gash is cut in the soft iron; eventually the face of the chisel breaks; all of which results are explained by the study of the science of elasticity as applied to the flow of solids and the exhaustion of metals.

(5) A better chisel is picked out and the hammering goes on all day without harm to the tool; such choice could not be made without a thorough knowledge of the chemistry and physics of steel.

(6) If the anvil be a stone and both it and the hammer be properly insulated and connected with an electrometer, every stroke would be seen to produce electricity; this sets us to thinking about piezo-electric phenomena, and we perceive that as every change of pressure produces electrical phenomena, therefore the electrified condition of the whole earth, with its resulting atmospheric lightning, may be in part the result of the crunching of the geological strata that we call the earthquake, an idea that was first suggested by Clerk Maxwell.

I need not weary you with illustrations of that which must be patent to every thoughtful mind; the general principle holds good everywhere and at all times that no inven-

tion can be made, no action taken, no great work accomplished on this earth, without involving many principles in nature that have already been recognized by scientists and others that still remain to be discovered.

You, therefore, do well to combine both physical science and the mechanical arts into one institution. Your object must be, on the one hand, to apply physics to the proper construction of machines and the daily needs of the artisan; on the other hand, you may hope to add something—perhaps much—to our knowledge of physics, through your ingenious machinery, your abundant experience and your keen thought.

The manifold and intricate connection between the sciences and the arts may be treated from several points of view. Let us first glance at the historical development of this connection.

II. EVOLUTION OF THE MECHANIC ARTS.

The mechanic arts may be said to have existed before the dawn of history; they were coeval with the evolution of the Aryan language. We trace the art of weaving, as we now know it, back to the time, 3,000 years ago, when it was already well advanced in India, but the word *to weave* is far older than that. We trace the potter's wheel back to the earliest archæological potsherds, perhaps 5,000 years, and know nothing of its far earlier history. We trace the arts of cutting, sawing and planing from our present magnificent machinery back to the first knives of jade used by the prehistoric Asiatic and American races. We trace our hoes, ploughs and cultivators back to the sticks and the forked branches that were used to scratch the soil by the first tribes of men, but how many thousand years ago no one ventures to say.

The modern railroad car, the elegant wagons and the fleet bicycles only became possible after the ancient architects had first learned to put rollers under the massive stone blocks and had put rude wheels to the carts drawn by oxen and to the wheelbarrow pushed by man.

The art of sewing leaves together, or that of spinning

threads must have been an early suggestion after man had learned to twist grass and twigs together to form crude ropes.

Our extravagant military engines, from the immense ironclads down to the Mauser rifles, go back step by step to the stones and slings, the bows and arrows, and the boomerangs of primitive man.

I should say that the mechanic arts had no definite beginning; they have gone through a process of evolution so gradual and gentle that we can at no time say "this was the beginning."

Mythology does, of course, tell us that Vulcan forged Jove's thunderbolts. To the mind of the child of to-day, just as to the childish minds of antiquity everything on earth must have had a definite beginning, there must have been some one who first taught us how. Therefore, the ancients demanded a cosmogony, a History of Beginnings, a Divine Creator and a simple tangible method of procedure as to His inventions and creations.

But the modern scholar who has studied carefully all the ways of nature among the plants, animals and rocks of this earth and the stars of the universe beyond us, perceives that a series of changes, a gentle and gradual evolution, has prevailed everywhere. We are, therefore, prepared to recognize that this same principle applies to the industries and to the arts that have been developed through the agency of man. We are but the agents. The Creator is working, but through us, not for us. He moulds the world, not as the potter does the inert clay, but as the wise parent does the mind of the intelligent child.

III. EVOLUTION OF INVENTIONS.

The crude devices of primitive man were improved by successive inventions. In the history of invention, properly so-called, the simple collocation and juxtaposition of two ideas is often the critical matter. It is not science, or study, or art—it is simply the happy accident that brings some one's mind two thoughts that are suddenly seen by the inventor to have an important relation to each other,

hitherto unsuspected. For instance, some one is anxiously looking about for a pigment that will produce a special tint of color. He is wandering along the roadside and sees the color he needs in a piece of stone or discoloring a ledge of rock. If his mind is ready to receive the suggestion, it becomes seed sown in good ground. The idea of grinding that stone into pigment immediately occurs to him. He proceeds to experiment, and not only grinds, but oxidizes and even roasts the stone. The invention was a matter of suggestion to the inquiring seeker, but the art was an application of physical and chemical science.

Man's needs have stimulated him to discover and invent. Those who enjoyed the best surroundings have generally brought forth the best results. Those nations and individuals who were unfortunate as to climate, soil, vegetation, minerals, water-power, etc.—those who had neither stimuli nor opportunities, did little. In proportion as we to-day associate ourselves with the highest science, we bring forth the best inventions and manufactures.

Some one asks why we cannot make a steamboat that will go fifty miles an hour by the use of the screw-propeller. The idea is good, but it is a mere matter of imagination, a dream, a useless suggestion until all the resources of physics and mechanics have been combined to evolve the modern high-speed vessel.

Professor S. F. B. Morse was an artist, but was also seeking to make some great invention. The idea of communication by means of electricity, with the speed of thought, early took possession of his mind and he was always on the look-out for some method of realizing the indefinite hope that haunted him. Ten years were spent in making every conceivable combination of electrical devices—but nothing came of them. At length Dr. L. D. Gale suggested that Joseph Henry's recent researches on the electro-magnet be put to use. That distinguished scientist was consulted at Princeton, and immediately it was found that the laws that he had discovered in relation to electricity and magnetism, and the apparatus that he had made were those appropriate to the Morse telegraph, that, in fact, he had one already at

work. Even if you do not agree that we ought to speak of the "Henry telegraph" and the "Morse alphabet," you will at least grant that every step in telegraphy, from its beginning to the modern perfection of the art, has only become possible by means of the knowledge resulting from investigations conducted by scientists, or by inventors who had to become scientific investigators before they could complete their work.

IV. INVENTION ASSOCIATES WITH INVESTIGATION.

We must be careful to recognize that the inventor is frequently also a scientist, and still more frequently is the scientist an inventor. The scientist cannot investigate without having instruments and apparatus, and must invent these to suit the needs of the case. The inventor frequently comes upon an obstacle that cannot easily be overcome until he has investigated some obscure point either in mechanics or physics. This principle is beautifully illustrated by the life and work of James Prescott Joule, who was the son of a brewer, and himself continued in that business for a long time. His scientific education under Dalton, in England, and Jacoby, in St. Petersburg, enabled him to fully appreciate the mutual relations of science and art. While others speculated on the use of the electricity from the galvanic battery as a motor, he, by studying the laws of thermodynamics, showed the exact connection between the amount of work that could be done by a pound of coal when burned in the furnace and a pound of zinc consumed, *i. e.*, burned, in the galvanic battery. He then proceeded to the determination of the so-called "mechanical equivalent of heat," viz., the fact that a unit of heat can only do 772 foot-pounds of work. He is justly considered one of the founders of the modern doctrine of the conservation of energy, whose principles must be obeyed by every mechanical device that man may invent. When anybody proposes to manufacture something out of nothing, no matter whether he calls it perpetual motion, or the Keely motor, or the liquid air motor, you have only to show him that he proposes to violate Joule's law and he must subside.

The changes of temperature produced by the condensation and rarefaction of gases, especially of steam, are vital to the working of the steam engine. These were early experimented upon by Espy, but more thoroughly by Joule and Kelvin; the arrangement of the cut-off of the steam engine must be made in accordance with Joule's laws if the machine is to work efficiently, as indeed he, himself, first showed in his paper of June, 1844. At that time he said: "The principles I have established lead to a theory of the steam engine very different from the one generally received. . . . Believing that the power to destroy belongs to the Creator alone, I entirely coincide in the opinion that any theory which, when carried out, demands the annihilation of force, is necessarily erroneous. . . . The theory here advanced demands that the heat given out in the condenser shall be less than that communicated to the boiler from the furnace in exact proportion to the equivalent of mechanical power developed."

V. MECHANICS, EXPERIMENTAL AND EMPIRICAL, ASSOCIATES WITH SCIENCE.

I choose the following case to illustrate this theorem:

In the "Philosophical Transactions of the Royal Society of London," for 1886, is a beautiful memoir on the theory or method of action of lubricating oils and other lubricators. This memoir, by Professor Osborne Reynolds, seems to be the first satisfactory effort to unravel the physical actions involved in lubrication. There had been abundance of previous experimentation for two hundred years past, and many empirical rules and tables had been formulated, respectively applicable to each set of experiments, but the special experiments made by Mr. Tower gave Professor Reynolds the first suggestion as to the truth concerning the method of action of the film of oil that we insert between a journal and its bearings, in order to diminish the loss of power by friction. Reynolds had previously conducted a beautiful set of experiments on the flow of liquids in tubes and very small channels, and had shown that, although the resistance to flow is ordinarily proportional to the square of the velocity,

yet there is a critical velocity at which it suddenly changes from the square over to the first power of the velocity. He was now able to show that lubrication is simply a case of the flow of a viscous liquid through a very narrow channel. When the journal presses upon its bearing, the intermediate space is perhaps the $\frac{1}{1000}$, or more likely $\frac{1}{10000}$ of an inch in thickness. This space, being filled with oil, constitutes the thin film that serves to convert the rubbing and tearing of the metals into the sliding and rolling of liquid molecules. It is as though we had inserted a myriad of minute steel friction balls between the journal and its bearings. You are all familiar with the thin films of the soap bubble. Perhaps you have observed that when the film is not too thin it may be said to consist of two surface films separated by a thicker layer of liquid. These two surface films may slide past each other. By careful watching you may see the beautiful spots of colored light rearranging themselves as the two surfaces draw nearer and nearer together and squeeze out the liquid between them. The thinnest part of the soap bubble is a film much thinner than that ordinarily dealt with in lubrication, while, again, the thicker parts are much thicker than lubricating films. By means of the apparatus invented by Plateau the properties of these thin films have been abundantly studied. The motions of the viscous liquid particles must obey the laws of mechanics, as at first clearly expressed by Stokes, Kirchhoff, Helmholtz, Stefan and other students of hydrodynamics.

The results of these difficult researches in molecular physics have a direct application to the lubricating action of oils. Professor Reynolds succeeded in elucidating the novel phenomena recorded by Mr. Tower and established an important verification of the assumptions on which our modern theories of hydrodynamics and molecular physics are founded. I may be allowed to speak more fully on this subject, because these ideas have not yet found their way into many text-books on machinery. Let us take up one simple phenomenon, viz., the heating of the journal and bearings. We have hitherto imagined that after the jour-

nal has worn a smooth bed in its bearings, and there is no objectionable and injurious heating or abrasion, that then its rapid revolutions proceed without the evolution of much heat. Now the fact is, that while the upper and lower surfaces of the lubricating film of oil remain in permanent contact with the steel journal and the brass box, respectively, or at least change very slowly and there is no abrasion of the metals, still the thin layer of intermediate liquid is being rapidly torn away and renewed. The viscosity of the liquid resists this sliding of one layer of its molecules past the other, and thus gives rise to heat; the inner layer of the liquid film soon becomes a surface layer where the molecules are under great tension, and this change gives rise to more heat. As long as the journal is revolving heat is being evolved by the compression and internal friction or motion of the molecules composing the lubricator itself. Often we do not observe this heat because it is carried away by conduction through the metals and by the least breath of air almost as fast as it is generated. Every one knows that the abrasion of dry metal surfaces evolves heat—but the abrasion of viscous films also does so. As the journal revolves rapidly it carries its thin film of oil into the crevice between the journal and the bearing; it is a V-shaped or wedge-shaped crevice, and as the film crowds into the wedge Reynolds speaks of it as going into the "on" side, because right above this crevice is the load bearing down upon the film. As the film squeezes through the crevice, being forced along by the rotating journal, it quickly approaches the off side of the load, where the pressure is taken off of it and it is again free to spread out over the journal: thus it is carried around until it again enters the "on" side and squeezes through a second time to the off side. You will see at a glance that the small area of film between the journal and the bearing on the "on" side must support the whole load, and this implies an enormous pressure, which, in the experimental work of Mr. Tower, was only 625 pounds to the square inch, but must be far greater than this in many of the cases that occur in actual practice. Of course, the laws that hold good for perfect

lubrication will not obtain for the case of imperfect and irregular supply of oil, or for cases where the lubricant has not the proper molecular and physical properties needed when very great pressures are involved. But when there is a full supply of oil and the pressures are not too excessive, then you will easily perceive that the film adhering to the journal and about to enter the "on" side of the crevice is not as yet under any pressure or constraint, except only that it is held to the surface of the journal by reason of some molecular attraction between the metal and the liquid. Ordinarily, we say that the particles of liquid cohere among themselves, while the liquid and the solid adhere together. Now, the liquid will not easily be forced from the free surface of the journal into that crevice between the journal and bearing where the pressure per square inch is so great, and yet it does both enter and pass through, and there is nothing to bring about this remarkable result, except the rapid motion of the journal and the adherence of the film to its surface. We must think of the liquid film as a small mass of matter thrown into the "on" side of the crevice with considerable velocity and, also, as dragged in by the journal. Its viscosity and its inertia combine to force it into the wedge-shaped space. It must be very considerably compressed therein. It must, also, have its molecules forcibly squeezed past each other as it passes through the narrowest part of the wedge and slips onward to the large space in the rear. Of course, also, its forward movement with the journal is slightly retarded in front and accelerated in the rear. But the most interesting feature is the pressure—the static pressure within every part of the film.

There must be a resultant pressure against the surface of the bearing and another against the surface of the journal. These would be normal to the surfaces and equal in intensity and opposite in direction if the journal were not in rotation, but when rotating, the pressure keeping the two surfaces apart is greatest in the front half of the lubricating film, while in the rear half it becomes negative, that is to say, it tends to bring the two surfaces together. This sur-

prising result may, perhaps, be easily reconciled with our current ideas if we remember that the same powerful adherence which carries the oil with the journal forward into the funnel must also, in the rear of the latter, carry it away from the funnel. As much oil must leave the funnel in the rear as approaches it in front. There is a push in front, but an attraction in the rear. It is evident, therefore, that the force that keeps the journal from absolute welding contact with its bearing is the adherence of the oil to the journal and the coherence of its own particles. The resistance that we call friction in a smooth-running journal is an exaggerated case of that which we call viscosity in hydrodynamics. It is the force required to make one layer of liquid glide past another.

The other friction that occurs when no lubricant is used, or when the supply of the lubricant is too limited, of course, involves the tearing asunder of the particles or molecules of the metals themselves. This abrasion is not considered in the theory of lubrication.

Professor Reynolds' hydrodynamic theory, as checked by Mr. Tower's experiments, seems to give us a complete statement of the relation between the frictional resistance, the load and the speed for any lubricant that is supplied in abundance, and he has given us a general formula applicable to all cases that can occur.

When there is but a limited amount of oil available, an increase in the load, *i. e.*, the pressure, will diminish the thickness of the film around the journal in general, but will increase the length of the pad of oil that bears the weight, thereby increasing the area of the surface films, whose sliding past each other produces the frictional resistance, and, therefore, increasing the friction. The relation between the increase in friction and the increase in load for this case is more complicated than for the case in which an unlimited amount of oil is available, which latter case is experimentally realized by wholly immersing the journal and its bearings in a bath of oil.

The result of the whole research is to show that, not only in case of intentional lubrication, but whenever hard sur-

faces under pressure slide over each other without abrasion, they are separated by a film of some foreign matter, whether perceivable or not; that the action of the revolving journal is to maintain the film between the surfaces at the point of pressure; that if there is any abrasion when the surfaces are well lubricated and well filled, it must be due to the foreign particles in the oil—particles introduced at the first grinding or subsequently as dust.

I may add that when the lubricant has thickened or is entirely absent, we have a condition analogous to that of the swiftly revolving wheel of soft lead, which is used to cut into the harder metals, to which I will refer later.

I give this long review of Reynolds' work as but one among many illustrations of the advantages that accrue to empirical mechanics when illuminated by sound science.

VI. SCIENCE STIMULATES THE MECHANICAL ARTS.

The demand for measurements of the highest attainable accuracy is characteristic of the study of astronomy and physics, and always keeps in excess, or, more properly, in advance, of the current state of the art of construction. Consequently, the needs of science have made many demands upon the mechanical arts, and have steadily stimulated their progress. Science and art mutually stand to each other as cause and effect. The demand has always exceeded the supply. The supply has always, eventually, responded to the demand. The patrons of physics, and especially of astronomy, have always been willing to pay for the highest art, and no instrument-maker of genius has labored without abundant recognition.

Consider the manufacture of optical glass, which has reached its highest development in such works as those of Chance & Co., Feil & Co. and the School of Glass Technology establishment at Jena (under the control of Schott and Prof. Ernest Abbe). Here are manufactured great plates of optically perfect glass, having any required characteristic as to refractive and dispersive power, or even as to elastic and electric properties.

The construction of telescope lenses as perfected by Al-

van Clark, and of microscope lenses by many artists too numerous to mention, all involve mechanical processes of the rarest delicacy, and illustrate how perfectly one class of men, the mechanicians, have been able to realize the ideals conceived by another class of men—the investigators.

The mounting of the great steel tube and all the accessories of the telescope, the construction of the revolving dome and the movable floor by such firms as Warner & Swazey, all demand the best engineering, while the delicate micrometer, with its perfect measuring screw, the spectroscope, the photometer, the camera, the chronograph and the clock, the transit instrument with its perfect pivots, the vertical circle with its delicate graduations, the altazimuth instrument and the spirit-level on which everything depends, each and all call for the most delicate manipulation, the most absolute homogeneity of material, freedom from internal strain, the finest work with the lathe, dividing and planing machines and numerous other characteristics of the highest type of the mechanical arts.

For two centuries past the stationary astronomical clocks and, especially of late years, the portable chronometers used by navigators at sea, by explorers on the land, by geodesists and astronomers everywhere, have been reckoned among the marvels of mechanism. Hundreds of men have directed their best thoughts to the perfecting of these time-pieces, so that they shall respond to the needs of the practical astronomers. From this work has resulted the possibility of the establishment of the manufactories of high-class watches on an immense scale, so that now every one purchases, for a few dollars, that which a century ago it was entirely impossible to obtain. We wind our watches daily and boast of their accuracy to within a few seconds, quite forgetful of the fact that the astronomer and mechanician had to combine together to evolve this great system by which a million of time-pieces of high character are annually manufactured for popular use. But, not satisfied with this, the scientist takes the most perfect specimen of all these and uses it in pushing his astronomical studies to a still higher perfection.

Astronomy is often called the parent of all the sciences, because it is said to have been the first in the order of development. But it has also been the foster-parent, because astronomers found it necessary to develop, encourage and protect every other branch of science in order that their own might prosper. Astronomy has demanded the most perfect apparatus. The command of large funds consecrated to this work by generous patrons has enabled astronomers to stimulate active minds and nimble fingers so as to secure those triumphs of accurate workmanship that are necessary to the advance of every branch of science. In this way the sextant and chronometer came to be devised for the navigator; the theodolite, the base apparatus, the pendulum apparatus and the spirit-level were devised for the use of the geodesist; the Gaussian apparatus for the study of terrestrial magnetism; the modern balance for the use of the chemist; the self-recorder for the use of the meteorologist.

When the investigator needs better apparatus, he usually invents or designs its necessary features and then calls in the mechanician to help construct it; the former discerns the sources of error and the latter devises methods to overcome them. Generally, the student leads the mechanician; science directs the art of the mechanic; the mind guides the hand.

The popular idea of science includes both the increase and the diffusion of knowledge; to the general English reader the scientist may be either a discoverer, an investigator or a teacher. But the teacher cannot exist without the discoverer. Since the investigator must add to the sum total of human knowledge in order that the teacher may have something to teach, therefore, he must know both what has been done by others and, also, how to improve upon that. He, therefore, it is who is the true inventor, the one who *finds out;* and it is he who in his desire to study deeper stimulates the mechanic to produce better tools and apparatus. Thus it is that both the astronomer and the physicist and all the special students of nature take a prominent part in the development of more perfect apparatus.

They must have the means to make better measurements of length, area and volume, of time, velocity and angle, of weight, mass, attraction and repulsion, of electrical current and resistance, density and potential, conductivity and capacity; of temperature and heat, expansion and radiation. They must have all the apparatus especially appropriate to the study of heat and light, elasticity, gravity and electricity. The best they have to-day will not be good enough for to-morrow.

VII. FUNDAMENTAL IMPROVEMENTS IN MACHINES FOLLOW THE DEVELOPMENT OF FUNDAMENTAL PRINCIPLES IN SCIENCE.

Every important advance in the mechanic arts has been preceded by special scientific investigation and the determination of data that were fundamentally necessary to the success of that particular advancement. This seems like a very strong and, perhaps, a rash statement. I may not have made an exhaustive examination of the subject; there may be an exception to the rule; but we shall find so many illustrations of its truth that we must accept its general application in modern times, whatever may have been true in the earliest stages of the arts. At the present time, those whose tastes incline them to research pave the road for those whose tastes incline them to invention and manufacture. The heroes of invention and manufacture would still be lost in the wilderness of ignorance had not the devotees of science prepared a highway and paved it with a solid Belgian pavement of blocks of knowledge on which all may march to success.

I will illustrate this by, first of all, considering the subject of the efficiency of a machine.

In the construction of a tool or machine every device has for its object to secure the attainment of some specific motion or result with the greatest possible economy of force, in the least possible time, with the least possible waste of material. The original source of our power may be falling water or tidal waves, the burning of coal or the consumption of some precious metal, it may be the wind or

the direct energy of sunlight, or that indirect effect of gravitation represented by the electric currents that flow through the earth and atmosphere. In extreme cases, we may go back to the old-fashioned sources of power, the horse, the dog or the man working in a treadmill, or travelling round and round in a circle. But in every case, we nowadays have to compute the ratio between the cost of the power and the value of the work that we finally get out of it. This involves essentially the question of the relation of the motor power itself to the amount of resulting work. This latter ratio we call the mechanical efficiency of the machine; the perfect machine of modern times is characterized by a large per cent. of efficiency. For instance, we use an axe to split logs of wood. A dull axe, or one whose blades are rough or wrongly inclined to each other, will waste a large percentage of our strength in friction and unnecessary resistances. After we have given it a sharp edge and a proper angle of cleavage, we still have to consider the ratio of its weight or mass to the power available in our muscles and the resisting power of the log that is to be split. With a small mass in the head of the axe, such as 3 to 5 pounds, we should in vain attempt to cut the tough wood that would yield to a heavier axe of from 5 to 7 pounds.

Among our natural sources of power we reckon the wind as one of the earliest to be used and still one of the most important. To increase and to measure the efficiency of a windmill is a problem that has taxed the genius of our best inventors and students. It is not measured by the quantity of work done per hour, but by the ratio of that to the work done by the wind in passing between the sails of the windmill. Having given up some of its momentum to the sails, the wind must still retain a large portion in order that it may move onward and make room for a fresh supply of air that is coming onward from behind. It would not be advisable to abstract from the wind more than one-half of its momentum, therefore, from this point of view, the efficiency of the windmill sail should not exceed 50 per cent.; this is the external efficiency of the mill. If now we compare the

work done at one end of the machine with the energy of the revolving windmill-sails at the other end, we obtain the internal efficiency of the mill, which in properly constructed apparatus may be as high as the factor for the best machinery of any other kind; but in fact, the windmill is not generally constructed with great care, and Prof. Franklin B. King, of Madison, Wis., finds but a small percentage for the best windmill investigated by himself.

The mechanical efficiency of a machine is now recognized as a matter of the very highest importance. Much of our manufacturing competition is based upon the relative merits and relative expenses of running our machines. The modern methods of measuring efficiency and of investigating the sources of waste emanate always from those who are fully alive to the laws of force involved in all mechanical operations. They are essentially due to the physical laboratory and the mechanical laboratory. They often involve mathematical considerations of a very abstract character. Many an engineer keeps the records of his indicator card and sums up the foot-pounds per minute in a mechanical sort of way that shows that he can have no conception of the labor given to the study of thermodynamics before this simple device could be made equally useful to the manufacturer and to the inventor. The former sees in it a record of how much his engine is wasting, the latter sees in it suggestions as to how to improve the machine. The indicator card is an application of physical laws to practical machine work that has during the past fifty years been quietly revolutionizing the construction and use of the steam engine.

The injector first made by Giffard, a French engineer, which, by the way, has received numerous important modifications by William Sellers & Co., of Philadelphia, must be allowed to be not an efficient machine from a mechanical point of view. But, from a thermal point of view, it is almost perfectly efficient, since all the heat of the steam and the feed water goes back into the boiler; it is this that enables it to add to the efficiency of the steam engine as a whole.

The Bessemer process for making steel is a good illus-

tration of a method that is highly efficient mechanically, thermally, chemically, and I may also say chronometrically, since the time required is reduced to a minimum, consequently also financially, and it is no wonder that we have now suddenly arrived at the age of steel as distinguished from the age of iron.

The process of welding by means of the electric current is another illustration of an economy of time, fuel and power that is truly remarkable. You will perceive that all these improvements were preceded by a long series of laborious scientific determinations of the necessary fundamental data.

The pumping of water by means of reciprocating force pumps, as distinguished from the rotary pumps, is a very ancient process, the crudeness of which, from a mechanical point of view, might have been thought to have been overcome by the rotary and centrifugal pumps. The reciprocating pump is still indispensable when great heights or resistances are to be overcome; but it is precisely also in this case that the strains upon the machinery are most dangerous to its welfare. Here come in the improvements made by your fellow-member, Mr. D'Auria, whose devices have overcome important difficulties experienced in other machines, while at the same time he attains a remarkably high percentage of mechanical efficiency. If his construction of tubes and his arrangement for the flow of water and diminution of shocks is properly analyzed, it will, I think, be seen to be the outcome of a long study into the flow of water in rivers and channels. His application of theoretical hydrodynamics to the construction of pumping machinery is a fine illustration of my general principle that all the higher improvements that our present types of machines have received or are still susceptible of, in order to become more perfectly efficient, can only come from that profound study of mathematical and physical principles that belongs to the scientific and technological courses of our universities.

If any further evidence were wanted, you have only to consider the other side of the case, viz., the fearful sacrifice of time and money, human thought and human life that is

represented by the thousands of useless devices that are annually patented by over-sanguine inventors. These usually proceed from men of little education or experience, who have heard, perhaps, that John Smith made a fortune out of his little invention, and vainly imagine that whatever is new and patentable is naturally of some value.

It would be impossible to quote to-night all the important inventions, even by members of the Franklin Institute, that illustrate the importance of economy and efficiency as the prime characteristic of any great invention, but I will mention, still, the brilliant invention of the sand-blast by Mr. B. F. Tilghman. This simple jet of air or steam with sand does in a few minutes the work of cutting that the finest engravers might spend years in doing. It substitutes machinery for the engraver's hand; but, of course, it cannot replace the artistic imagination of the famous cutters of gems. The mechanical principles involved in this process were explained by Professor Osborne Reynolds in the *Philosophical Magazine* for November, 1873. The first and fundamental item is a law of impact, viz., that at the instant of first contact the pressure between two bodies is independent of their size, their mass or their velocity, but depends principally upon the density of the bodies and their hardness, so that a dense soft body may cause as much pressure as a less dense but hard body.

Singularly enough, very much the same principle applies to the soaring flight of a horizontal plane surface flying through the air. If the plane were to fall vertically from rest to the ground, it would quickly set all the air below it in motion outward in all directions, and would fall more rapidly because falling with the moving air; but, when flying horizontally, it experiences at every moment the necessity of giving motion to a fresh mass of quiet air. It falls more slowly, as if experiencing a greater resistance. In this way, the air, considered as a soft body, causes an upward pressure sufficient to support a heavy body for a long time. So in the sand-blast, the first effect of the impact of the grains of quartz is to impress on the molecules of the softer glass a slight motion, which is a certain percentage

of the movement of the harder particles of sand, and just sufficient to tear them away, one at a time, from the rest of the glass.

You will perceive that Reynolds' law applies again to the polishing burr-wheel, to the spinning of sheet iron and tin plates and to the cutting of stones, metals and glass by the edge of the rapidly-revolving wheel of soft lead or copper.

Professor Reynolds shows that, in order to produce the same effect, a sand-blast that is cutting into lead must have a velocity about eight times as great as when cutting into glass, the ratio depending upon the relative densities of the lead and glass.

The geologist has occasion to apply these same principles, since the sand-blast is always at work eroding the face of the earth with the help of wind and water.

I cannot refrain from quoting another modern invention that illustrates the recent application of simple physical principles to machines. I do not know the personal history of the inventor of that which we call the "Babcock Cream Separator," but he must have been a student of physics who first proposed to substitute centrifugal force for the force of gravity. As you all know, the particles of cream rise to the surface of quiet milk because of their buoyancy. Cream is specifically lighter, or has less density, than water. Gravity pulls down the water harder than it pulls the milk, and therefore the water pushes the cream up by a hydrostatic pressure that it owes to the attraction of gravitation. Mr. Babcock puts his milk into a rapidly-revolving cylinder; the rotation gives rise to a centrifugal force, all particles have the same rotatory velocity, but, each particle of water being denser than a particle of cream of the same size, is pressed outward by its centrifugal force more forcibly than the particle of cream. Thus, therefore, a great centrifugal force is used in place of gentle gravity to generate a great difference in centrifugal pressure, and thus quickly force the separation of the water from the cream.

In a very analogous way, the drier in a modern laundry, whirling rapidly around, separates the water from the wet cloth by centrifugal action.

So, also, the whirling atmosphere of the earth drives cold air from the north pole toward the equator, pushing aside the warm south winds.

Among the many branches of physics that are studied in the laboratory, none has more interest than the flow of metals, whether elastic or non-elastic. All that we have learned about this subject has found immediate application, first, in the improvement of the ancient process of wire drawing, second, in the modern process of rolling rails, again, in the still more modern process of drawing the seamless tubes, and, finally, in the rolling of the immense plates for our ironclads.

The steam locomotive is often said to have begun with the work done by Oliver Evans, of Philadelphia, in 1772. The improvements made by George Stevenson, of England, for a while gave English engines a high position as models; but since those days Philadelphia has come to the front and the Baldwin Locomotive Works are now sending their engines to England herself. You all know from personal experience that the modern locomotive embodies at every point the best thought of investigating physicists and illustrates again the absolute necessity of securing for our inventors, engineers and manufacturers the best graduates of our best technical schools.

You will not, therefore, be surprised if I emphatically urge upon your attention the general principle that the relation of astronomy and physics to the mechanic arts is not wholly an historical one, in that astronomy and physics preceded and fostered all important improvements, nor is it merely one of dependence, in that astronomy and physics look to the mechanician for the perfect apparatus. It is not merely a relation, but a relationship and a close one. It is a twinship, in fact, a Siamesian twinship where the blood of each flows through the other. If art is the right hand, science is the left. If one is the tool, the other is the worker. Neither advances without the other; if one steps forward to-day, the other steps forward to-morrow.

Among the most important features of the development of modern mechanics has been the introduction of a class

of machinery sometimes designated as machine tools, by which we mean machinery that is more or less perfectly automatic and is designed for the construction of many copies of some one part of another machine rather than for the direct manufacture of crude material as in textile work. These parts were formerly made entirely by hand; they were forged or filed, sawn and hammered, scraped and polished until they were of the proper size, shape and smoothness. A watch, for instance, is a machine intended to keep correct time; every portion of it, from the minutest screws and pivots to the chasing on the outside of the cover, was formerly done by skillful hands and the expenditure of time and labor was enormous, while the resulting mechanisms always presented minute differences, such that no two similar parts of two watches could be interchanged. Now, however, tools are available by which every part of the watch is made by machinery. The human hand and eye scarcely ever intervene, the similar parts are always interchangeable and the resulting watches are, to a very great extent, perfectly comparable with each other in their performance as time-keepers. Just as a file is a simple tool in the hands of the workman, so the Waltham lathes, planing machines, engraving machines, screw-cutting apparatus and drilling machines are *complex* tools, namely, machine tools, for manufacturing the parts of the watch.

The history of the modern development of the mechanic arts is the history of the application of the highest science to the perfection of the machine tools.

But a machine tool may be almost useless without the steady supply of power necessary to drive it. The foot-lathe is a simple machine tool, but it cannot be applied to fine work on a very large scale, such as that now required, owing to the unreliability and irregularity of the power that is used as the prime motor. The development of the modern lathe and its application to innumerable problems was necessarily dependent upon the invention of the steam engine, the turbine wheel and the dynamo, all of which furnish an abundant and perfectly equable supply of power that can easily be transmitted to any desired spot.

Among the important machine tools we may quote the lathe as applied to the cutting of screws and the production of all manner of symmetrical surfaces; the planing machine for flat and curved surfaces; the drilling machine for cylindrical pits; the boring machine for hollow tubes. Modifications of the lathe are seen in the vertical drilling machine and the slot-drilling machine. The machinery for making the blocks that are used in connection with tackle was one of the earliest machine tools. The trip hammer, as modified by Nasmyth into the steam-hammer, works as if endowed with intelligence. The rivet machine replaces hundreds of laboring men, but makes it possible to set thousands at work on other lines.

A very important class of tools is that for testing and measuring the dimensions and the fitting of the various parts of a machine. When once a perfect machine or tool has been made, there immediately comes a demand for perfect copies of it, and these cannot be made without accurate measuring machines and machine tools that are correspondingly accurate. The great advantage to be derived from the system of manufacture in which each part of a machine is identical in size and shape with the similar parts of other machines was appreciated in England many years ago and was especially insisted upon by Sir Joseph Whitworth. The perfect measuring machines that are necessary to carry out this idea have, however, been manufactured and used most freely in this country, William Sellers and Brown & Sharpe being well known in this work. The average errors of properly made interchangeable parts of a machine will not, in the present state of the art, exceed $\frac{1}{1000}$ part of an inch, and even in the largest cylinders and pistons of a steam engine freshly turned out of a huge lathe there ought not to be an error of $\frac{1}{100}$ part of an inch or the ten thousandth part of their own diameter. Still greater accuracy can be attained whenever needed.

Some of the heaviest and, at the same time, most accurate machine tools are those built for the purpose of manufacturing heavy ordnance, armor plate and the machinery of the great naval vessels of the world. In the construc-

tion of these the best engineering talent and the soundest scientific knowledge are always utilized. They illustrate the best that can be done at the present time; but who can tell what another year may bring forth?

We have spoken of the mechanic arts as though we have to deal only with working tools and moving machinery; but, of course, all great stationary engineering structures being themselves the products of the mechanic arts, illustrate, on the one hand, the perfection to which the arts have attained, and, on the other hand, the physical problems that must be solved in the course of this progressive development of the arts. Within our own lifetime we recall such monuments as the tubular bridges over the Menai Straits and over the St. Lawrence, the suspension bridges over the Niagara and the East Rivers, the London Crystal Palace of 1851, the Eifel Tower at Paris and the Ferris Wheel at Chicago. These were only possible after machinery had been devised for rolling the iron and steel, cutting and bending it, punching and twisting it in all directions, and, finally, testing every portion of the structure as to its strength and expansion with stress and temperature. Even in the fine arts, our pianos, organs and brass instruments respond to the increasing knowledge of physics and the finer arts of the modern mechanic. Only the violin remains as yet unimproved by the progress of the mechanical arts.

Perhaps the modern bicycle illustrates, in a small way, that which the dynamo and electric motors do in a large way, the fact that at every turn our knowledge of physics is of vital importance to our future progress. It is about thirty years since the first French bicycles made their appearance. The idea, that is to say, the invention, was ingenious, but it was impossible to popularize this vehicle in its first crude stage. The wheels were simply those of a small ordinary wagon; the tire was iron for the sake of durability; both front and back wheels were too large, so that an unnecessary strain was brought upon the rider, which proved disastrous to many. Since those days successive changes have taken place; the iron tire is replaced by the india rubber pneumatic tube; the heavy wheel of

the wheelwright gives place to the elegant steel wheel and frame; the chain and sprocket give place to perfectly bevelled cog-wheels and rods. The fatiguing journey then indulged in as an athletic exercise now becomes the regular and easy work of an hour in discharge of one's daily duties, to say nothing of touring for pleasure, day after day, all summer long. Every step in this progress has been, and every step in future development will be, but an application of principles discovered and taught in the physical laboratories of our universities.

VIII. EDUCATION IN SCIENCE AND TRAINING IN ART ARE MUTUALLY HELPFUL.

If science both stimulates the arts and feeds the artisan with necessary physical data; if the laboratory of the investigator and the workshop of the artisan are thus intimately associated together, how is it with the young men themselves who are to become either artisans or scientists? How is it with the education of our youth? Fortunately, laboratory practice or the teaching of physics by means of systematic personal experimentation in appropriate laboratories has been introduced into all of our best institutions of learning. It is now clearly recognized that the only satisfactory education is that which gives the student both a knowledge of the discoveries of others and personal practice in the art of discovery. The study of nature is not conducted by haphazard methods, but is itself a highly developed art. The courses in practical arts and the courses of scientific study should not be widely separated, but should be considered as being essential portions of one course of education.

In an address delivered in 1883, at Johns Hopkins University, the Hon. S. T. Wallis said that no phrase illustrates the action and reaction of the practical man and the scientist upon each other better than that due to Mr. Huxley: "While all true science begins with empiricism, it is true science only in so far as it strives to pass out of the empirical stage into the deduction of empirical from more general truths." The average citizen imagines that the learned man

of research is set apart from everyday life. He needs to be reminded daily that the electric light, the incandescent Welsbach, the brilliant acetylene, the ordinary gas light are all evolutions which the practical world owes to the physical laboratory; that not only the electric motor, with its halo of mystery, but the ordinary steam engine, which is but little less mysterious to the uninitiated, and the turbine wheel, which everyone imagines he can admire intelligently, are wholly the creations of the practical scientists who have given of their knowledge freely to the world of mechanic arts.

We must not attempt to separate investigation and education from invention and manufacture. We need to bring them closer and closer together than ever. I may quote from Dr. Wallis the case of a fireman or engineer of many years ago, in the days when the explosions of boilers were more frequent than now, and were an important object of investigation by the Franklin Institute. His boiler had exploded disastrously; he was called upon to give his testimony and proceeded to state that "no one could know anything about these things except a man who had been brought up in the boiler room, and that the particular explosion in this case was, undoubtedly, due to the gases in the boiler." When asked what gas, he replied with an air of triumph: "How can I tell? I was not inside the boiler." Fortunately, such ignorant men are not now allowed to have control of boilers and human lives. Safeguards and protective devices of all kinds have been attached to the boilers, and, indeed, all other kinds of machinery; but, after all, the essential element of protection lies in the training and intelligence of the men in charge. It will be a happy day when every university has attached to it a school of mechanical engineering, so that the practical world of action and work may profit all the more by the scientific wisdom and broad learning of university scholars.

These crude remarks of mine will, perhaps, have already accentuated the importance of a thorough education along mechanical and physical lines, if one intends to devote his life to the improvement of the mechanic arts. As I have

said before, one may, by a fortunate and accidental collocation of ideas, be put in the way of making an important invention or improvement; but the chances are all against this unless one has been pursuing such a course of education and training as will have fitted him to recognize the importance of the ideas when they suddenly occur to him, and to embody them appropriately in the metal and material of which his machine is to be made. Many a bright thought occurs to those of us who have not trained skill in the art of composition, and, therefore, we fail to become poets and musicians; many a man witnesses daily some little operation going on about him, but fails to make it the basis of a new process in the mechanic arts, because his thoughts do not run that way. In general, the most important improvements in machinery originate with those whose daily work familiarizes them with the special subject and its needs. It is fortunate that the tendency of the present generation is very decidedly toward the thorough education in physics of those who inherit a liking for machinery, in the belief that thereby they will certainly be better prepared to contribute toward the advance of our arts and to compete with those who, throughout the world, are revolutionizing the progress of civilization. America holds its own with England and Europe in this respect.

The following prominent training schools may be mentioned:

The Sheffield School of Engineering, at New Haven, founded in 1847, but in 1860 changed to the Sheffield Scientific School of Yale University.

The Lawrence Scientific School, with its recent addition of mechanical engineering, founded in 1847, at Cambridge, Mass.

The Massachusetts Institute of Technology, founded in 1861.

The Worcester Polytechnic, founded in 1865, at Worcester, Mass.

The Packer School of Engineering, Lehigh University, Bethlehem, Pa., founded in 1866.

The Stevens Institute, at Hoboken, founded in 1868, opened in 1871.

The Sibley College of Mechanical Engineering and the Mechanic Arts, at Cornell University, Ithaca, N. Y., founded in 1870.

The Case School of Applied Science, at Cleveland, O., founded in 1877.

The Rose Polytechnic, at Terre Haute, Ind., opened in 1883.

The graduates of these institutions are now everywhere coming to the front in our workshops, in the Patent-Office, in the manufactories and even in our politics, for, of course, the practical mechanic and engineer must be represented in the State and Federal legislatures.

I notice that in Germany both merchants and manufacturers have lately united in stimulating the education of mechanics and artisans as an important step toward improving the quality of their goods and the condition of German trade. The manual training schools, the workingmen's trade unions, and other interested parties in the city of Hanover have resolved to establish advanced lecture courses, in which artisans and apprentices in all trades shall have an opportunity to complete their education in mechanics. Only those will be admitted to the classes whose theoretical and practical knowledge is such as to give promise of success. Great care will be taken to teach young men how to obtain the most practical advantages from the knowledge imparted in the classes. A permanent exhibition of all power machines and tools will be established.

The needs and opportunities of a great technical college were forcibly set forth in 1893, in an article by Dr. R. H. Thurston, Director of the Sibley College at Cornell. After enumerating the large sums of money devoted to the support of educational institutions, he called attention to the fact that technical education in the mechanic arts, strictly so-called, had not—and we may still say *has* not—been sufficiently provided for. The present demand for trained electricians but emphasizes the great need of training in every department of the mechanic arts. The provision for culture in literature, history, pure science and the fine arts is far better; but that for technical instruction, manual training

and the art of doing as well as thinking still calls for attention. Laboratory or engineering research is especially to be desired. Every piece of machinery that we are using to-day is in itself a field for investigation as to whether it is doing its work with the greatest efficiency and in the best manner possible; but such investigations demand a previous knowledge of the laws of mechanics and familiarity with mathematical methods such as the technical schools alone can give.

The passage of a nation from barbarism to modern civilization occupies a long time, and is always attended with a great increase in density of population, and a great rivalry between individuals competing for success. The interaction between all classes of the community grows more intense; those who are on top struggle to keep their vantage by calling to their aid all the resources of power and intelligence. Experience has demonstrated that in this contest intelligence wins, and that knowledge is power. There can, therefore, be no doubt of the wisdom and statesmanship of the community that improves every possible opportunity to develop the natural resources of its territory and the intelligence of its own citizens. Both in Europe and in America universities and surveys, arts and manufactures, morality and science, health and prosperity go hand in hand. Victory flies to those who are best prepared; peace rests with those who nurture the arts of peace.

President Eliot has nobly said: "It is the regular pursuits and habits of a nation in time of peace that prepare it for success in war and not the virtues bred in war that enable it to endure peace."

From this point of view—the highest that any philosopher has yet attained—we see at a glance the wisdom of those citizens who have encouraged the development of both material and intellectual resources. I join the material and the intellectual together, for neither is of use without the other. If it is the mind that studies nature, it is also the mind that conquers nature. The intellect is developed, strengthened and quickened in this struggle with nature. A university includes every possible variety of education,

theoretical and practical: mechanics and physics, the laboratory and the workshop. It stores up knowledge but only to diffuse it again in perennial streams.*

[Remarks of Prof. A. S. Mackenzie, Bryn Mawr College, "On the Claims of Abstract Science to a Place in the Franklin Institute."]

PROFESSOR MACKENZIE:—Professor Abbe has given us to-night a beautiful example of the value of theory when turned to practice; we all know of his researches on clouds and the clearness of the earth's atmosphere, but to-night he has descended from the clouds and shown his power to provide with a clear atmosphere the subject of the relation of pure science to the mechanic arts. I have listened to his remarks and those of Professor Mendenhall with very great pleasure, but with a good deal of trepidation, for I fear that what I may have to say will but traverse the ground they have already so fully covered. Perhaps, however, I may be pardoned some repetition, for I believe that too much stress cannot be laid on the importance of the subject upon which Professor Abbe has chosen to address us, and that progress in the future is to be made only by the theorists and the practical men keeping in the closest touch with one another's aims and needs.

It seems to me that the event in the history of the Frank-

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* Even while this was being said in Philadelphia, a most favorable endorsement of these views was offered elsewhere, in that a stirring letter from Andrew Carnegie turned the subscription lists for the new University at Birmingham, England, very decidedly towards the promotion of applied science rather than merely literary and scholastic work. The immense iron and steel interests that center in Pittsburgh owe their development to Carnegie's fore sight in securing young scientific experts to manage each department of his works. He urged that Birmingham should make science the principal and classics the subsidiary department of education; that the Midlands might retain its prominence as the British manufacturing center.

The question is not one of markets or of transportation, but of skill and economy of manufacture. He who has such a thorough understanding of chemistry and physics that he can manufacture the best article, will be sure to find a market and to overcome the difficulties of transportation. "Knowledge is power."

Mr. Carnegie's great gift to Birmingham will surely redound to the benefit of the whole English-speaking world.

lin Institute which we are assisting at to-night is a notable one in its progress, and one which shows the high ideals of the Society and the broad aims of those to whom its management and direction are entrusted. We learn from the full title of the Institute that its aim is *the promotion of the Mechanic Arts*, and we read of its sections devoted to Mechanical, Electrical, Chemical, Mining and Metallurgical Engineering as a matter of course. At first thought it might cause surprise that it had a section devoted to theoretical chemistry, and that it was proposing to add a Physical and Astronomical Section; it is, however, but living up to the many-sided character of the man whose name is so intimately connected with it, and whose investigations in the realm of abstract science are an integral part of our studies of to-day; and I think that not until now can the Franklin Institute be said to have reached the standard set by its founders, or to have been quite rounded out in its various functions.

The line of progress and development of the Society has been a natural one in this new and rapidly-growing country, where the production and improvement of appliances for the rapid development of the country's enormous resources have called to their aid the best thought and energies of its people. As a consequence, the technical side of science has been advanced more rapidly than its theoretical side; it is true we have had a Franklin and a Henry, but the production of such men has been spasmodic, and until quite recently the study of physical science was but nominally existent in this country, whereas now great strides forward are being made and the names of Rowland, Newcomb, Gibbs, Michelson, etc., are known in every corner of the scientific world. It is more than a coincidence, I think, that to-day the Franklin Institute is forming a section devoted to Physics and Astronomy, and that the physicists of the country meet at New York to-morrow to found an American Physical Society; it proves that at last there is an awakening to the necessity of the study of science for itself, and to the belief that we are fit for better things than to be a nation of shopkeepers and inventors only.

To the problems of engineering and technical science in its widest sense the Franklin Institute has in the past devoted most of its energies, and with great and growing distinction: the inventor or thinker to whom a John Scott or other medal of the Institute has been awarded has a recognized standing the world over, and the Journal of the Institute is consulted regularly by all engineers who wish to keep abreast of the progress in their special fields, and to follow the newer and more important processes and developments of their chosen work. But surely it is not necessary to add that, insomuch as it has not had among its sections one devoted to the study of physical science for itself, without thought of material gain or useful adaptation, it has lacked one very necessary part of an advanced organization devoted to mechanical science. I consider it a great privilege to be present at this auspicious opening of the Physical and Astronomical Section. The able address of Professor Abbe, whose reputation, already so well known, will not suffer from the interesting lecture we have just listened to, has emphasized the absolute necessity of a close communion between the men who are willing to be the devotees of pure science and those whose ideals are in a direction equally valuable, and the results of whose labors are felt directly by each one of us at our every turn. It is upon this necessary working together of these two groups of men that I think we should at this meeting lay stress.

A science must exist before applications of it can be made, and hence the two divisions of the great work fall into the hands of two different sets of workers; and the nature of the work and the composition of mind required are quite different in the two cases. Not to the pure scientist belongs all the credit for the making of a science; the mechanic or engineer can, by constant thought and application, so get at the very heart of things that he becomes a co-worker of the theorist and advances our knowledge of the inner workings of nature; for a mathematical knowledge is not essential, it is a help and a valuable one, and the man armed with this weapon for attacking a problem is at an advantage, provided he does not become lost in his sym-

bols; and it must not be forgotten that Faraday wrought out his great work in the field of electricity without mathematical equipment of the higher variety. It is, however, to the theorist, not to the technical man, that we must look for the advancement of science; but this advance can never be so rapid as it should be unless both theoretical and technical men recognize their mutual dependence. Du Bois Raymond has somewhere remarked that there is no abstruse investigation into nature that does not at some time have its practical application, and, this being so, how essential it is that this investigation should proceed on a clear knowledge of the work done and being done by practical men. Perhaps no better illustration of the value to the theorist of a knowledge of the technical requirements of his subject can be found than in the development of the study of thermodynamics; it was the work of Watt and his successors that led to the brilliant achievements of Carnot, Kelvin, Clausius, Maxwell, Hirn and others. Our whole knowledge of the laws of energy is almost a consequence of the researches called into being by the demands of engineers to know the principles underlying the working of the heat-engine. The theorist thus receives a constant guidance and check as well as incentive, and is forced to give a reality and definiteness to his speculations which might otherwise remain in the clouds and whose full significance would be known not even to himself.

But to the technical man the assistance of the theorist is of much greater value. In addition to the direct aid afforded to the engineer by the new principles and discoveries of the thinker must be mentioned the fact that the theory not only guides the engineer in the direction of possible development and improvement, but that it acts as a beacon to warn him from the many directions in which his genius and labor would be barren of results, because he aims at the impossible.

There never was a time when, more than now, the technical man must work hand in hand with the pure scientist. It requires the finest theoretical knowledge to devise a telegraph by the aid of which eight or more mes-

sages can be sent along a single wire in each direction at the same time, and yet we ordinarily consider telegraphy a purely technical subject. The engineer who would keep up with the pace which science is making must consider himself always in the schools; he must be trying to keep step with the changes in the theory and with the growth of knowledge as proclaimed from the studies and the laboratories; he must, if he would win distinction, have the training which fits him to seize the idea behind the theorist's symbols and forms, and strikingly apply it to the everyday problems in which his interests and labors lie.

The brain of the genius who can fasten upon the practical consequences of an idea brought forth by the mere thinker is one of the very highest order, and he deserves the merit he receives, and the world is quick to reward him in its substantial way, although the world is little able to discriminate, and is willing to believe the scribbler of any magazine article who prophesies plausibly a sudden demolition of the laws of nature which the labors of the greatest thinkers have placed on the most enduring bases. Just now we can see an example of such a thing with regard to the law of the conservation of energy; we are threatened with most improper doings by liquid air, and we have not yet forgotten the Keely motor. It is to the credit of the scientist that he is willing to give his life to the prosecution of learning for its own sake, and that, too, when an understanding and appreciation of his labors must be given to few. How common it is to hear that man who has made some application of value (measured in money or utility) lauded above the originator of the idea. One hears of this or that inventor of the electric lamp or dynamo, but not of Faraday, who made an electric arc fifty years earlier, and produced the electric current by induction and foreshadowed all its applications. One hears of a Hertz or a Marconi, with their electric waves and wireless telegraphy, but how seldom of a Clerk Maxwell, whose seething brain put forth the thoughts of which these things are but adaptations. How often is Lord Kelvin's name connected with the problem of submarine cabling? One is almost tempted

to say that the person of so-called average intelligence gives in his heart greater credit to the inventor of "see that hump?" than to the discoverer of the law of gravitation. Surely equal credit must be given to the originator of an idea with him who applies that idea to the purposes of mankind; and it must come home to us how necessary is the existence of a close bond between these sets of workers, so that each aids the other and to each is given the credit which is his due.

Now I believe that not only will the founding of a physical and astronomical section bring about good results of this kind to the Franklin Institute, but I consider that it is only a beginning in the direction in which such an institution should be expanded. It should have its staff of professors, whose only duty it should be to pursue original investigation, and the results of whose work should be made known to the world through the Society. Of course such things cost money, and being a practical people we hesitate to give our money to what we please to call unpractical purposes. I hope, however, that we have come to the conclusion that a full return for the money so spent is bound to come back to us in overflowing measure, though in indirect and unseen ways. It seems that our benefactors who give of their wealth to advance education are unwilling to pay for pure science; they willingly give their money to found and endow libraries, they give freely to art collections and to museums; but what cases can we recall of the founding of a laboratory for research only, a place where a Rowland could be put and told to go ahead regardless of expense and enrich the world's treasure-house of thought? The German Government has such an institution, and yet I would be sorry to see ours try to imitate it; for it would be difficult every four years to find a man of the right political complexion to take a well-earned turn at the "job." At the Reichsanstalt, to which I refer, and with which Helmholtz was connected in his later years, is a vast equipment, with its experts, to be counted not by units, but by hundreds, who devote their time not only to standardizing apparatus, but also to the devising of the best and simplest

forms of instruments and to the production of new ones; and in addition to all this is Professor Kohlrausch, with a staff of fifteen or twenty assistants, whose only aim is original research in the field of physics. All the products of these men's brains and the results of their labors are given freely to the world. I know of nothing similar in this country in the domain of physics; Harvard College has one of its departments, the astronomical observatory, devoted entirely to research. Professor Pickering and his associates give no lectures and no instruction in the observatory; they are expected simply to use their best efforts to promote our knowledge of astronomical science, and to this end are provided with a staff of forty assistants, and a fully-equipped observatory and library. What better thing could be done by one of our moneyed men, eager to utilize his great wealth for the good of mankind, than to found, in connection with this and similar institutions, a professorship in physics, assuring to one qualified to fill it a liberal stipend (for even a Newton must eat) and all the appliances and assistants his genius can employ?

Perhaps this has carried us too far into the future, and whether we shall ever come to this I do not know; but at any rate I believe that the Franklin Institute has made a move to-night which will redound to its credit and usefulness, and I have taken great pleasure in being present at its inception.

[Abstract of remarks of Dr. T. C. Mendenhall, President Worcester Polytechnic Institute, Worcester, Mass.]

Dr. Mendenhall spoke substantially as follows:

"The excellent and carefully prepared address of Professor Abbe leaves little to be said by those who follow him. It is a real pleasure, however, to be able to congratulate the Franklin Institute on the realization of a plan which is a recognition, tardy though it may be, of the intimate relations between the mechanic arts and physical science, or, as some of us would be inclined to say, the dependence of the former upon the latter. When I read the subject for discussion I wondered how it could be a subject of discussion at all, for I am sure everybody knows and admits

that progress in the mechanic arts rests upon and is measured by progress in the physical sciences. But it is no ordinary event in the history of either that the Franklin Institute, which may be justly considered the foremost organization in the country, whose primary object is and always has been the higher development of the mechanic arts and the encouragement of American invention, has organized a special section for the better development of its interest in the physical sciences. When one reflects upon the splendid work of the Institute in its chosen field, the outlook for the future of this new section of physics and astronomy is most promising, and we are all confident that much important work will here be done.

It is impossible to speak in this hall without constantly-recurring thoughts of the pioneers of American science.

It is entirely natural that the present should appear to be the golden age, and among the historians of science in this country it is too common to pass over the seventeenth and eighteenth centuries as relatively unimportant.

As a matter of fact, some of the most brilliant of America's contributions to science were made before the beginning of the nineteenth century and, counted in proportion to the population, the number of eminent scientific men in those days was fully as great as now, and along some important lines their share of the world's work was greater. Perhaps the first contribution from America to the proceedings of a scientific society was the first communication of Gov. John Winthrop, of Connecticut, to the Royal Society of London, of which he was one of the earliest members.

Another Winthrop, of the same stock, Prof. John Winthrop, of Harvard College, was also a frequent contributor, and doubtless did more to kindle and keep alive the fires of colonial enthusiasm for physical science during the eighteenth century than anyone else. But the one great figure of that period was one whose name and deeds are inseparably related to this city and in whose memory this institution was founded. The world has produced few, if any, more brilliant men than Benjamin Franklin. It is with

only one phase of his intellectual activity that we are interested to-night, and in that alone, as a physicist or natural philosopher, no one will deny that he must be reckoned among the very foremost. There is one quality of his scientific work to which I want to invite especial attention; it is the almost ever-present practical end towards which nearly every investigation was directed. On account of the great lustre of his researches in electricity, it is often forgotten that he enriched nearly every department of physical science, and although he evidently did not lack capacity for that keen enjoyment of discovery which depends upon discovery alone and is indifferent to practical results, it is everywhere evident that with him the possibility of turning a scientific experiment or principle to good account as a means of bettering the condition of his fellows was paramount. There is a certain class of scientific men, not large and not increasing, we are glad to note, among whom it is the fashion to speak with what they believe to be a "fine contempt" of applied science, and who, having never succeeded in discovering anything of any particular value or use, pride themselves on pursuing science for the sake of science. And we have all heard of the mathematician who thanked God that he had at last discovered a formula of which it would be utterly impossible ever to make any practical use. But this doctrine has not been held by those most entitled to distinction in the annals of science, and Franklin was a notable example of those who believe that the noblest ambition by which a man of science may be stirred is the ambition to discover laws which may be utilized in the amelioration of the almost necessarily harsh conditions by which mankind is surrounded.

It is difficult to address a body of scientific men in this place without thinking of another great name, that of one who stood almost at the beginning of that long and unbroken line of astronomers for which our country is justly famous. And in thinking of Rittenhouse in Philadelphia one is likely to turn from the contemplation of his splendid career as an astronomer to that incident, so characteristic of the men of his time, in which the man of science became, at the

behest of the Committee of Safety, the clockmaker again, designing and casting clock-weights in iron which were to be exchanged with the inhabitants of the City of Brotherly Love for leaden weights, to be moulded into bullets, which contributed to the founding of a new nation. During the life of that nation the most marvellous changes have been wrought in the material condition of man and his relations to the planet which he inhabits. We have ourselves witnessed so many of these changes that detailed reference to them is unnecessary, but we may profitably inquire concerning the underlying cause of such a prodigious revolution. To my mind it is found and found only in the discoveries in physical science, and in their application to the control and direction of the forces of nature. Man lives in this world only by the continued transformations of energy, and his comfort and happiness depend largely on the amount of energy he is able to transform. It is not long since his only supply was that furnished by the muscles of his own body, but during the nineteenth century he has been able, thanks to physical science, to draw upon almost inexhaustible sources from without, and this is why he has progressed by leaps and bounds that have exceeded the most extravagant imaginings of our ancestors. This progress cannot be attributed to war, for war has existed since the dawn of history, and it has failed to lift man above the slavery of unintelligent toil. Nor is it due to religion, nor literature, philosophy or art, for all have flourished for ages without materially altering the relation of man to his environment. Science, with its unerring processes of observation, experiment and precise measurement, has inaugurated the peaceful revolution in social relations and material conditions which the nineteenth century now passes on, still incomplete, to the twentieth.

The pen has conquered the sword, but the yard-stick is potentially the master of both.

Mechanical and Engineering Section.

Stated Meeting, held Thursday, March 9, 1899.

MECHANICAL APPLICATIONS OF COMPRESSED AIR.

(Abstract of remarks by Mr. W. L. SAUNDERS, M. Am. Soc. C. E., Member of the Institute, in opening the discussion.)

(*Continued from p. 55.*)

The profile of the One-hundred-and-twenty-fifth Street line shows that the grades to overcome fairly represent average conditions in New York. The grade from Fort Lee Ferry east to the Boulevard being 1·96 per cent., while at the New York Central Railroad tunnel crossing the maximum grade is 7·7 per cent. for a short distance, which is just as difficult to start the car upon as a long grade of the same ascent.

In the following statement of operating expenses, the coal and water items include all that has been used at the compressing plant during this period, and the labor account includes, in addition to the operating employés, a night watchman, record keeper, and also switchman for a portion of the time. It must also be borne in mind that the fires are kept under boilers for twenty-four hours, although the compressor only runs seven hours daily.

Actual average cost per car mile for entire period—seven months—125·16 miles per day:

Coal	$0.0563
Water	.0103
Oil and Waste	.0013
Power Plant Labor	.1261
Conductor and Motorman	.0608
Repairs Car Equipment	.0038
	$0.2586

Average present cost per car mile, with one-car service performed—78·09 miles per day:

Coal	$0.0675
Water	.0113
Oil and Waste	.0017
Power Plant Labor	.0833
Conductor and Motorman	.0608
Repairs Car Equipment	.0038
	$0.2284

Average present cost per car mile, with two-car service—156·18 miles per day:

Coal	$0.0433
Water	.0103
Oil and Waste	.0013
Power Plant Labor	.0833
Conductor and Motorman	.0608
Repairs	.0028
	$0.2018

If the proportion of labor actually utilized in this service is considered, the expense would only amount to $0.1791 per car mile at present.

Present number of employés, six besides conductors and motormen.

The reason for the present cost of operation being lower than the average for entire period is that the number of employés has been reduced, in addition to a less air consumption by the car. The number of employés at present is, however, sufficient to operate a fifteen-car service, so that the proportion of labor charges per car mile is still very high.

At a recent conference of several engineers, who investigated the cost of operating the American Air Power Company's system in behalf of a street railway now operating a large number of cars at intervals of one minute, it was determined, after careful examination, and agreed that for the items above enumerated the cost per car mile would in no event exceed $0.085, and that with a large equipment of cars in a service like that performed on One-hundred-and-twenty-fifth Street the cost would only be $0.0756 for the same items now costing $0.2018, while operating the two-car service. This would make the total operating expense of such a road about 12 cents per car mile.

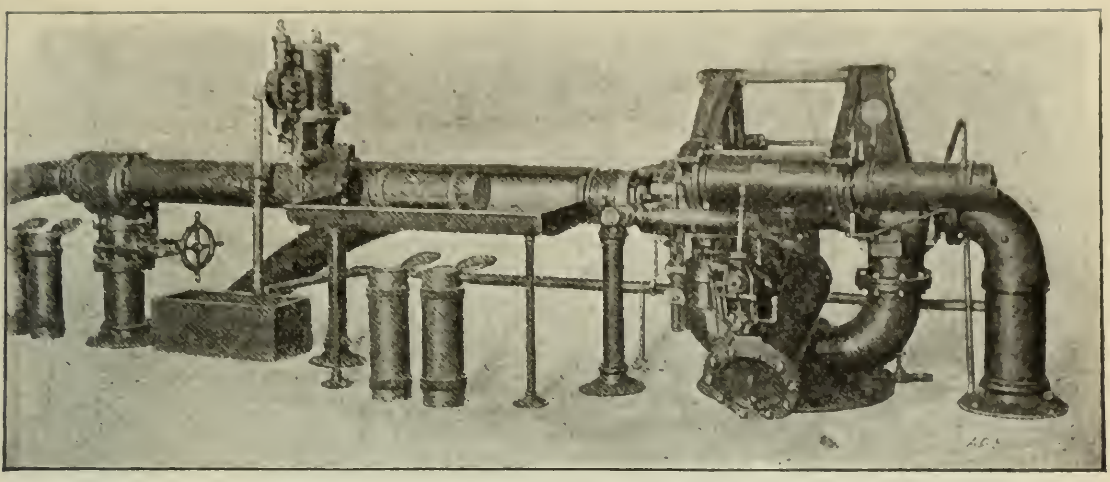


FIG. 12.—The Batcheller system of pneumatic dispatch. Sending apparatus and open receiver, Produce Exchange Line, main post-office, New York City.

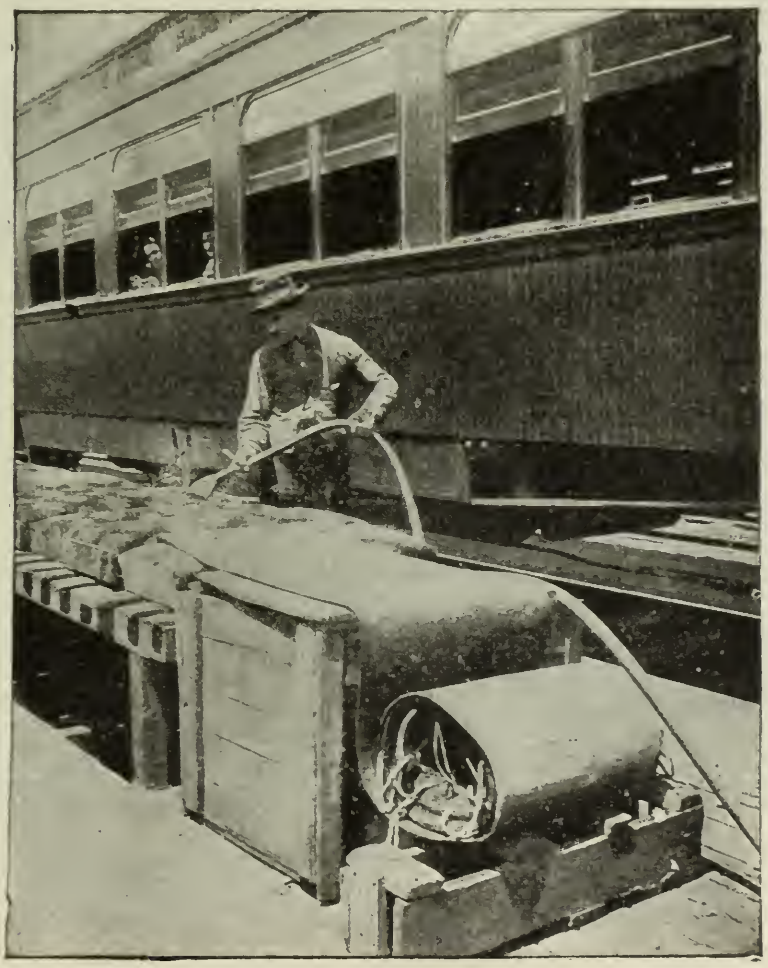


FIG. 13.—Cleaning car cushions and carpets by compressed air.

For the benefit of any who may not be familiar with the operating cost of so small a number of cars by mechanical power, the following data is furnished:

In the recently published report of the operating ex-

FIG. 14.—Painting by compressed air.

penses of twenty-two electric roads in Connecticut for 1896, the West Shore Street Railway Company, West Haven, is reported as operating precisely the same mileage, namely, 4·11, with the same number of cars in service, having, how-

ever, only five employés, and the average cost of operation per car mile is shown as $0.2991.

In the published report referred to, the average cost of

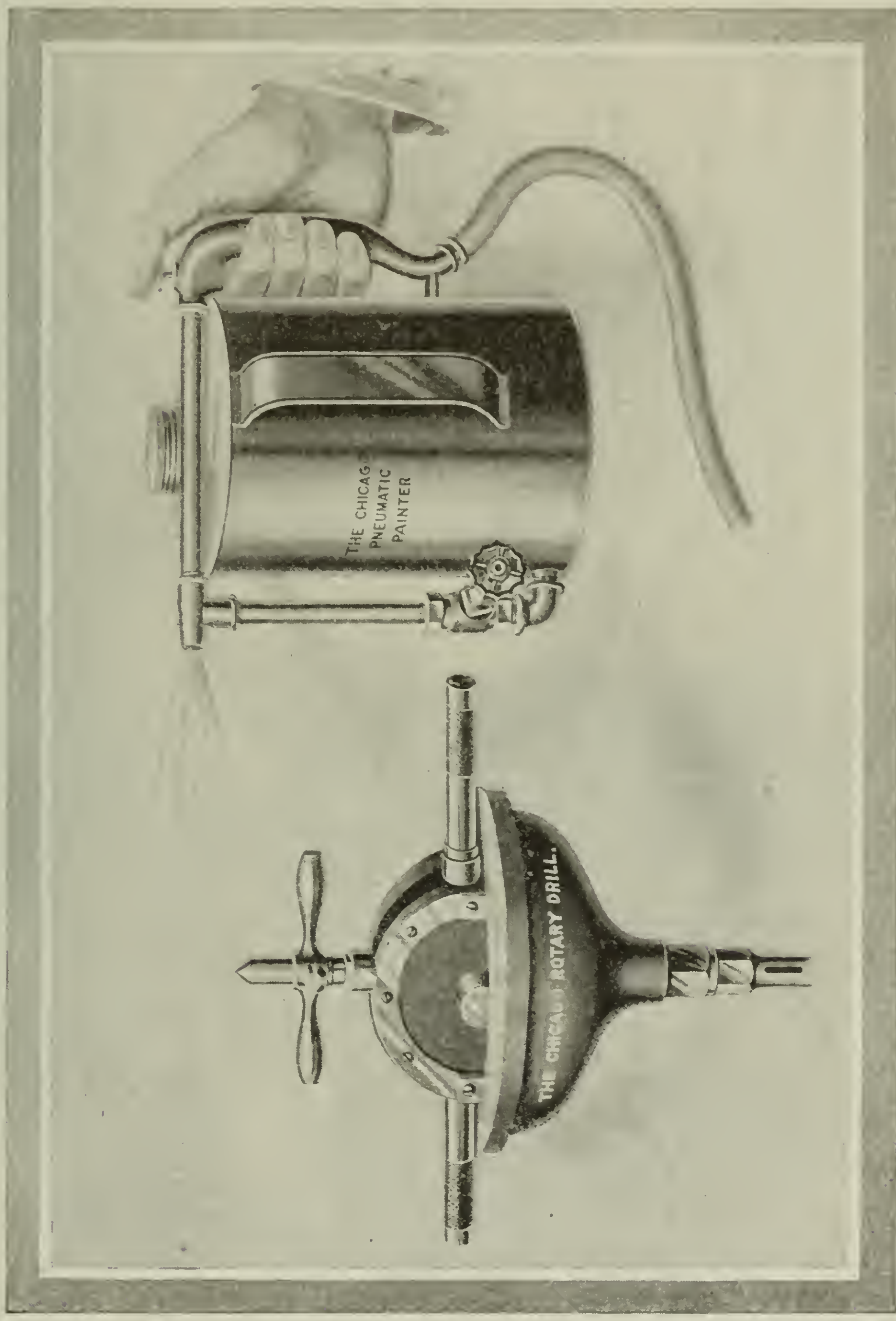


FIG. 15.—Painting by compressed air.

operation per car mile of the twenty-two roads given is $0.1444; and in the twenty roads having the items of mo-

FIG. 16.—Granite surfacing machine.

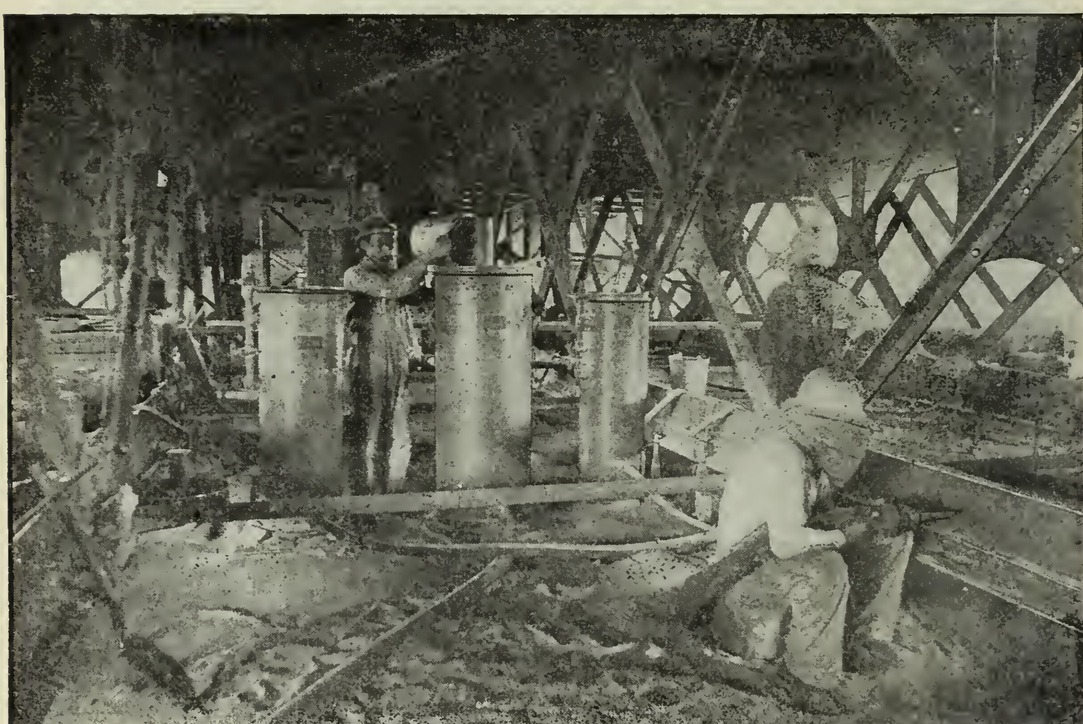


FIG. 17.—Sand-blast in operation.

tive power, and line repairs given, the average cost appears as follows:

Motive Power, Average	$0.02816
Line	.00270
	$0.03086

The average consumption of free air per car mile for the seven months' service of air cars on One-hundred-and-twenty-fifth Street has been 477·7 cubic feet. During the severe snow storm of December 16, 1896, the cars performed

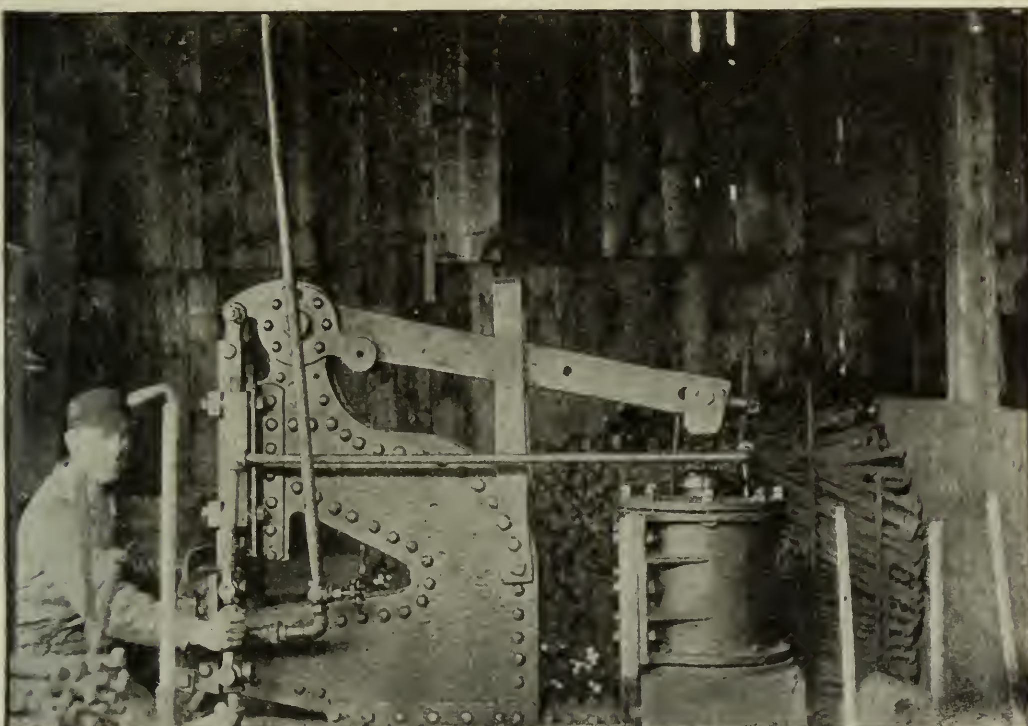


FIG. 18.—Pneumatic scrap shears.

the schedule service with promptness and regularity, carrying 20 per cent. more passengers and using 22 per cent. more power than the day previous. In comparing results with an electric road in this vicinity, it appears that, with 33 per cent. less service than the day previous, the load on the power-plant was about 80 per cent. greater.

During the last week the average consumption of free air per car mile was only 414 cubic feet, and many of the trips were made on considerably less than 400 cubic feet.

The actual cost of compressing air to 2,500 pressure per square inch, and storing for use in a modern air compressing plant operating with condensing engines, including coal at $2.75 per ton, water at $1.00 per thousand cubic feet, oil and waste, the removal of ashes, labor, repairs and maintenance of power plant, depreciation, and interest on cost of entire power-plant including buildings, for compressing plants of the following capacities, based on the consumption of 2½ pounds of coal per hour, per horse-power for twenty hours per day, will not exceed the following figures:

FIG. 19.—Surfacing railroad track by means of compressed air.

Cost per 1,000 cubic feet of free air compressed to 2,500 pounds pressure per square inch:

Station Capacity.	
500 cubic feet per minute	$0.0675
1,000 " "	.0571
2,000 " "	.0469
3,000 " "	.0419
4,000 " "	.0394
5,000 " "	.0375
6,000 " "	.0359

Station Capacity.	
7,000 cubic feet per minute	$0.0342
8,000 " "	.0326
9,000 " "	.0312
10,000 " "	.0300

Responsible parties will guarantee that the cost will be less than stated, and the writer believes that the cost in highest grade plants can be reduced fully 25 per cent.

Assuming the average consumption of air per car mile can be kept as low as at the present time, the average cost

FIG. 20.—Pneumatic punch.

of motive power per car mile on the above basis would range from $0.0124 to $0.027, or an average of $0.0197; and even if 477·7 cubic feet, the same as averaged for the past seven months in regular service, the cost of motive power per car mile will range from $0.014 to $0.032, or an average of $0.023. Placing these figures against the cost of motive power as averaged in the Connecticut electric roads for 1896, the results seem to show considerably in favor of compressed air as a motive power.

This cost of motive power, based on twenty hours' service,

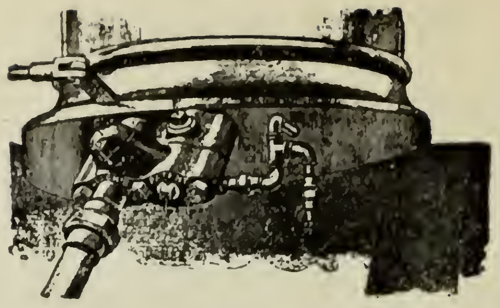


FIG. 21.—Pneumatic track-sander.

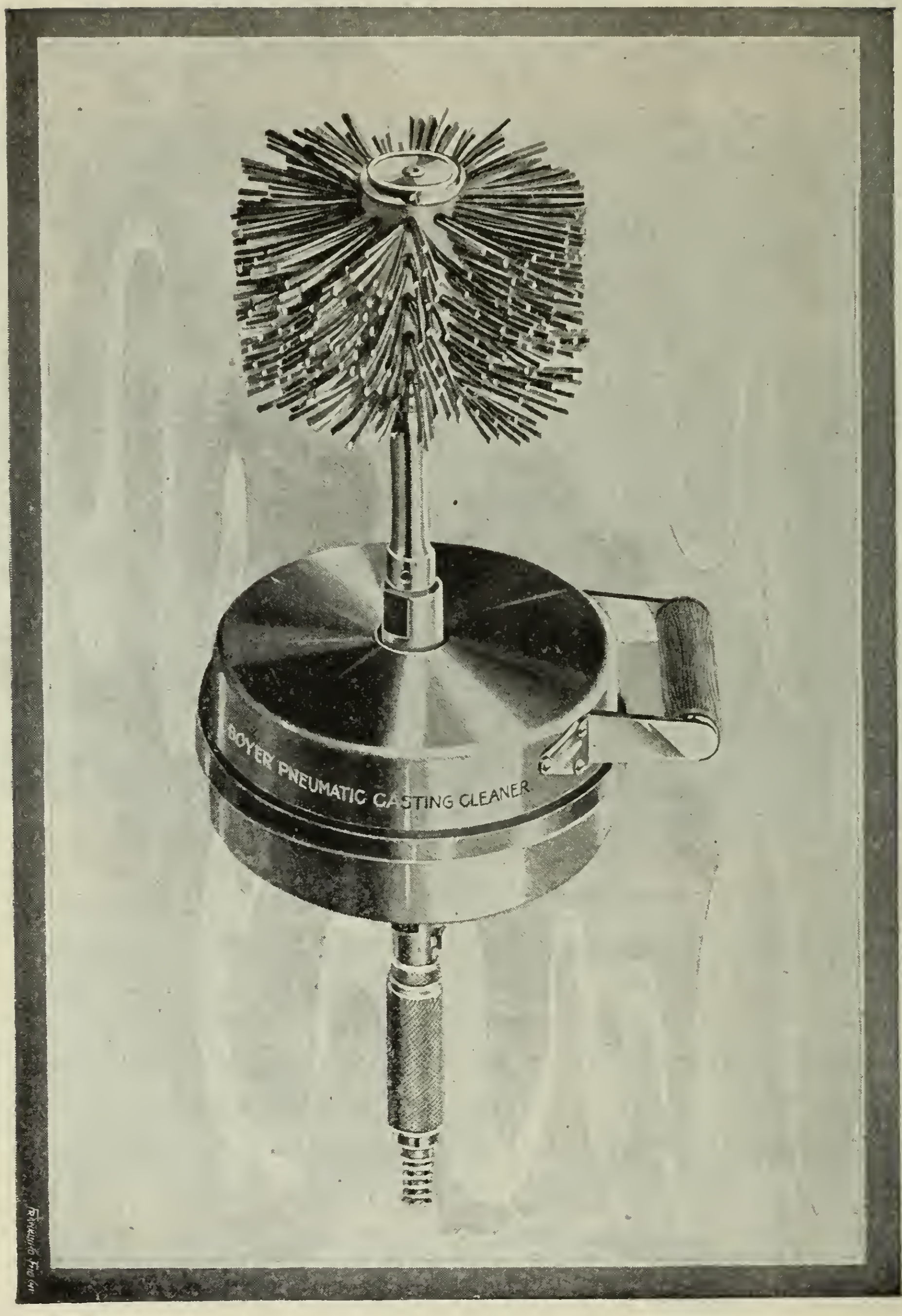


FIG. 22.—Pneumatic casting cleaner. Weight, 10 pounds.

does not represent the lowest cost that is available for the different capacities in the best practice for this reason, that in a compressed air plant having station storage reservoirs for accumulating the air, the engines can be

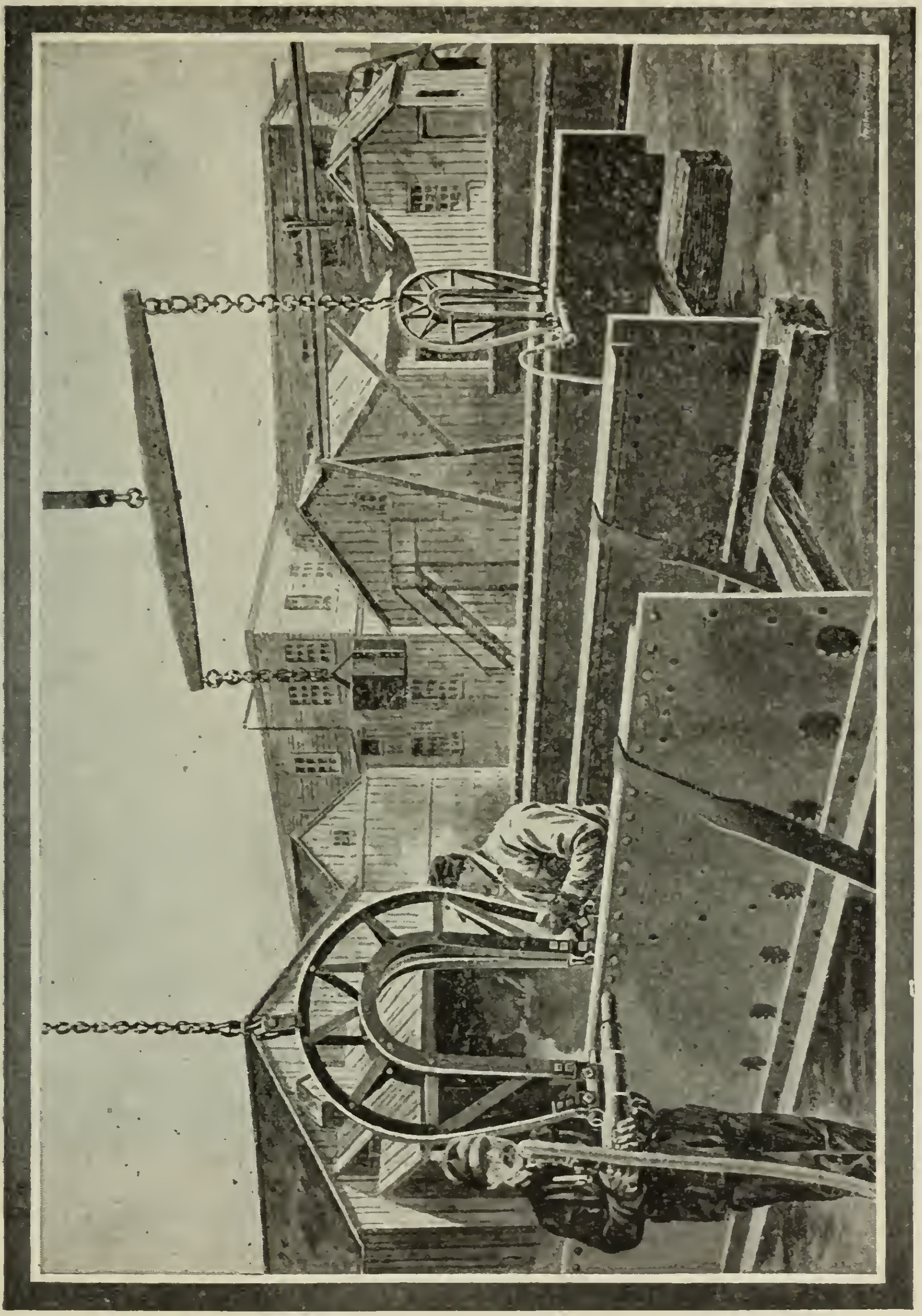


FIG. 23.—Pneumatic riveter.

worked at a uniform load at the most economical point of cut-off for, say, sixteen hours, after which the engines may be shut down and the power-plant charges stopped.

At the One-hundred-and-twenty-fifth Street compressing plant, the engine is operated only about seven hours daily, while the cars perform a twelve-hour service from a seven-hour station duty.

The process of operating the compressed air system on One-hundred-and-twenty-fifth Street is as follows:

FIG. 24.—1¾-inch Keller pneumatic hammer, caulking seams of high pressure digesters.

The air is first compressed by a steam-actuated air compressor, which is compounded in three stages from which the air passes through a cooler and dryer and is accumulated in a nest of Mannesmann steel flasks, which are all con-

nected in multiple by a series of headers or manifolds, in which stop valves are placed for controlling and confining the air to be stored at a maximum pressure of 2,500 pounds per square inch. A pipe leads from this air storage to the car house charging stand, placed alongside the track, which consists of a copper pipe in three sections, having a

FIG. 25.—View of pneumatic stone hammers at work on statuary.

controlling valve and flexible joints and a charging nozzle at the end. All the joints and the nozzle are self-packing, so that no leakage has occurred in the seven months' service. After the car has been connected by inserting the nozzle in a pipe at the side of the car track, the charging valve is opened and contents of the station storage flasks admitted

until the desired pressure—2,000 pounds per square inch—is registered by the car storage gauge. Then the charging valve is closed, and a small bleeding valve in the charging pipe opened, permitting the high-pressure air in the short length of pipe to escape, at the same time a check valve in the car piping closes automatically, preventing any escape of air, after which the nozzle is removed and the car ready for another seventeen miles' service. The entire time occupied, including connecting and disconnecting in actual daily service, takes less than two minutes, and has been done in less than one minute in numerous trials.

[*To be concluded.*]

Mining and Metallurgical Section.

Special Meeting, January 25, 1899.

MALLEABLE CAST IRON—Its HISTORY in the UNITED STATES.

George C. Davis.

Malleable cast iron may be roughly defined as occupying a half-way position between ordinary gray cast iron and wrought iron, as it possesses some of the qualities of both. This definition is not technically accurate, but serves rather to designate the place occupied by malleable iron in the commercial world.

Ordinary cast iron is a very complex alloy of iron with carbon which exists in several forms: silicon, phosphorus, manganese, sulphur and small proportions of other elements. As we all know, it can readily be cast into intricate shapes. It cannot be bent or forged, and it is brittle under shock, especially in light sections. Wrought iron, in its most refined form, is practically pure iron, and can be easily forged, and can be bent or twisted even when cold without fracture. It cannot easily be cast, but can be welded, a property not possessed by cast iron.

Malleable cast iron, or malleable iron, as it is commonly

called, is made from pig iron low in silicon, sulphur and phosphorus, and from which the carbon has subsequently been largely removed by annealing at a red heat in iron ore, mill scale or some other porous or infusible substance. When cast the iron is white in fracture and as brittle as glass, owing to the carbon which is present to the amount of about 3½ per cent., being in chemical combination with the iron. During the annealing at a red heat, the carbon, which is at this temperature in a state of solution in the iron, gradually diffuses. As it comes into contact with the surrounding packing it is oxidized and passes off as a gas which can be seen burning at the cracks in the clay luting of the pots. There is a variable amount of carbon retained in the casting, but it exists in a form like graphite in ordinary cast iron, that is to say, it is disseminated throughout the mass somewhat as mica occurs in granite. The flakes of graphite lie between the particles of iron, and form, as it is said, "planes of weakness." The diffusion of carbon in iron, even at a bright red heat, takes place slowly, and hence only castings of small cross-sections can be decarbonized to any appreciable extent. In castings less than ¼ inch in diameter practically all the carbon can be removed.

We have, then, as a result of the two processes, casting and annealing, a product which has first been formed in any desired shape and by its subsequent treatment converted to a state approaching wrought iron. We should therefore expect its physical properties to be between those of cast and wrought iron, and this we find to be the case. Its tensile strength, 45,000 pounds to 52,000 pounds per square inch, is more than cast iron, but slightly less than wrought iron; its elongation of 3 to 7 per cent. is much greater than cast iron, which is practically *nil*, and much less than wrought iron. We find, on trial, that malleable iron can be bent or twisted and forged to some extent, but not so much as wrought iron. The preceding remarks apply to light work, say to an inch in thickness or less. It is proper at this point to speak of another function of the annealing process as applied to heavy work, such as castings for farm implements and car couplers. As before stated, castings of this

class cannot be decarbonized to any appreciable extent, but they are rendered soft and strong. Such articles cannot be bent as much as the decarbonized castings, owing to the graphite forming planes of weakness, as noted above. We have, then, two classes of malleable castings, the small decarbonized articles and the larger articles containing nearly all their original carbon, but in a changed form. Each class of castings is admirably adapted for its own purpose. It may be questioned, if both classes are equally strong and soft, why is it necessary to decarbonize the smaller castings merely to increase their toughness? The answer is that in small work this quality is essential. Many small articles (bits, for instance) are cast open and "closed up" after inserting a ring; or, in assembling bits, parts are frequently upset or headed like a rivet. Thus, for small work it is highly desirable to have decarbonized iron to obtain the bending and cold forging properties.

Little has been written of the history of malleable cast iron, and, so far as I am aware, no account has ever been published of the beginning of this industry in the United States. I will endeavor to describe the practice in earlier times, the difficulties encountered, and will briefly mention some of the earlier foundries. The first malleable iron castings of domestic manufacture were produced in Newark, N. J., in 1826. Seth Boyden, to whom belongs the honor of doing this, was a native of Foxboro, Mass., but settled in Newark, in 1815, when in his twenty-seventh year. As a boy he worked at farming and occasionally at a furnace operated by one of his uncles. He attended school for only a few short terms, but this by no means ended his education, for he continued his studies by himself, especially in those natural sciences that would aid him in his labors. He showed to a very marked degree the traits of the stock from which he sprang. Mechanical ingenuity and skill with tools came to him naturally. During the course of his long life he was occupied with many of the arts and sciences, and so great were the benefits conferred by his many inventions and improvements on existing processes, that the citizens of Newark have erected a statue to his honor. Much

of the apparatus with which his experiments were conducted was made by his own hands. He made, among other things, a telescope, microscope, electrical apparatus and engraved a label for his books. Such work as this was usually done at odd intervals, or after the regular work of the day was over, and was to him rather recreation than serious business, but it serves to show his versatility. Many claims have been made for him as being the inventor of various processes. His original inventions were numerous, but his best and certainly, from a commercial standpoint,

Seth Boyden, Inventor.

the most important work was done in perfecting the ideas of others. There are few inventions which are not in dispute, and it is often the case that after learned men have written articles proving to their satisfaction their own side of the case, the archæologists step in and state that the Chinese or ancient Egyptians knew all about the article in question several thousand years before Christ.

Boyden is credited with inventing a machine for making wrought iron nails, a machine for making brads and files, a

machine for cutting and heading tacks and a machine for splitting leather. He also made the first patent or glazed leather, as it was then called, produced in this country, and carried on quite a business in this article for some years in supplying harness-makers. He built locomotives and made many improvements in their designs. In this connection it is interesting to note that he built a locomotive called the "Cometa," for the Cardenas Railway, of Cuba, and went there himself, in 1841, to put the engine in operation. One of his most important inventions was a machine for forming hat bodies, which he patented. This was the only patent that Boyden ever took out. In later years, when old age had incapacitated him for active business, he turned his attention to raising new and improved varieties of strawberries, and succeeded in this as in other things. It was characteristic of the man that a problem once thoroughly mastered, he turned his attention to some new process. He seemed to care only for mechanical success, any profits he might derive from his labor being merely useful to enable him to experiment in some other line. It seems incredible that he should have accomplished so much, but his life during the threescore years in which he was actively engaged is a good illustration of the endurance and persistence of the hardy New England stock. He took little care to protect his own interests and died, a poor man, in the year 1870.

Soon after Boyden settled in Newark he was engaged in the silver-plating business and it is possible that this was indirectly the cause of turning his attention to malleable iron. A large part of his business was in plating carriage and harness hardware. In those days such articles were necessarily quite expensive, as they were made by hand from wrought iron. It is evident from Boyden's notes that he had learned that such articles could be cast and rendered malleable by annealing, but he evidently knew nothing of the details of the process. General Runyon, in his address at the dedication of Boyden's monument, said: "What is called malleable iron was known before Mr. Boyden discovered it, but he invented it as truly as ever a man invented anything wholly new and previously unknown." This view

has been held by many, but I believe it to be clearly in error, for in experiment No. 6 of Boyden's notes, he says: "A piece of English M. iron was in, but no important alteration." Again, under the date of August 4, 1826, we find the entry, "50 pounds Sprue, 50 pounds Pig, White, when baked a perfect resemblance of some English of the same size." This proves that at about the time Boyden began his experiments he had in his possession some malleable castings that had been made in England.

Let us turn for a moment to note the progress of this industry in other countries. Reaumer had published the fundamental principles of the process in the year 1722, and some years later patents were granted in England for softening castings by annealing in ashes. This process applied to such castings as nails, anchors, cannon, chains, forge hammers, etc. In 1804 Sam Lucas, of Sheffield, took out a patent on malleable iron, but he believed the difficulties to be insuperable and so made no use of his patent in a commercial way at least. His brother, Thomas Lucas, shortly after took up the matter, and succeeded in producing cast cutlery which, according to Parks' "Essay on Edge Tools," 1815, would take as fine a polish as the best cast steel. These articles were sold under the name of run steel. According to Percy and other authorities, the use of malleable castings rapidly extended, and by 1830 the industry had attained large proportions. The castings were used for cutlery, pulley blocks, carriage and harness hardware, and a variety of other purposes. Thus we see that malleable iron had been manufactured in England for some years before Boyden began his experiments.

In 1828, the Franklin Institute of this city offered a silver medal for the best specimen of annealed cast iron, to consist of not less than one dozen pieces. The report of the committee of that Society says: "Premium No. 4, for the best specimen of annealed cast iron, is awarded to Seth Boyden, of Newark, N. J., for specimen No. 163, being an assortment of buckles, bits and other castings, remarkable for their smoothness and malleability. This is the first attempt in this country to anneal cast iron for general purposes that

has come under the knowledge of your Committee, and success attending it, fully entitles the maker to a silver medal." From the wording of this report it is evident that the committee were aware of the manufacture of malleable castings abroad, and in awarding the medal to Boyden it is merely for excellence of workmanship on a novel article. There is no hint in the wording of the report of the process being regarded as an invention of Boyden's, prior or otherwise.

His experiments with malleable iron of which we have record extended over a period of six years. At first they were carried out in his house, the iron melted in a crucible in a forge fire. The castings were annealed in a small furnace, using hard coal, erected in his fireplace. In this way he made a series of twelve experiments to determine the

best pig iron to use, the best packing, proper temperature for annealing, etc. A part of experiment 6 is here shown, which illustrates a series of diagrams used in some manner to keep track of the various mixtures of iron. These diagrams are supposed to refer to the shape of the castings and are possibly cross-sections of them. In some cases we can trace a relation between the shape of the diagram and the proportion of iron used.

One-seventh wrought, six-sevenths Sterling, fine, strong, superior, good before anything I have ever seen.

One-fourteenth wrought, six-fourteenths Sterling, nearly the same as above.

One-twenty-eighth wrought, six pieces Sterling, nearly the same as above; a little darker.

Sprues of above, nearly the same as above; the above bent to less than ½-inch circles.

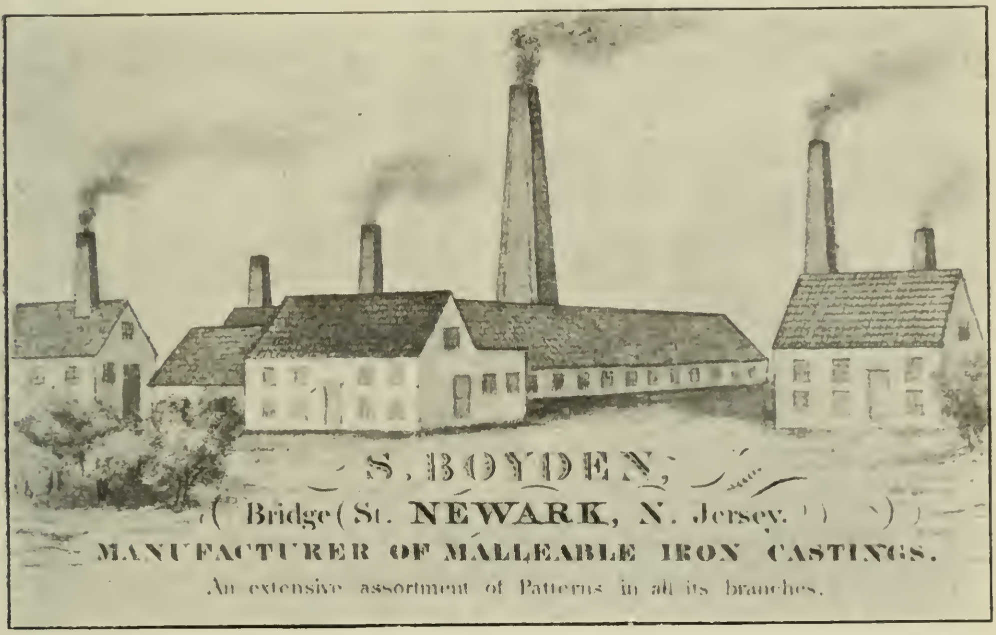
He was sufficiently encouraged by the results obtained to erect a foundry, which was started in the summer of 1826,

for on July 4th of that year is the entry under the heading "Experiments in foundry." His observations and deductions were exceedingly shrewd, though his explanations were often at fault. When we consider how little was then known of chemistry and metallurgy this is not surprising. The selection of a suitable pig iron occasioned him little difficulty, as it is evident from his notes that he very soon came to the conclusion that Sterling was the best. He tried many brands separately and in various mixtures. He mentions Sterling, Peru, Carthage, Bennington, Vt., three brands of Salisbury, viz., R., B. & Co., H. C. & Co., and C., S. & Co.; two brands of Egg Harbor, viz., Etna and Weymouth; Sheldon, Washington, Amenia and Scotch. This latter was soon given up, the notes experiments 10 and 11 stating that it was brittle. The reasons for this we can well imagine. Few of the brands here mentioned are familiar to the foundrymen of to-day. Etna and Weymouth recall to us the industries which once existed in the Jersey pines. The furnaces in this district used bog ore, and their output was mainly devoted to castings. It is of some local interest to note that the first cast-iron water pipe produced in this country was made at Weymouth Furnace, which was located on Great Egg Harbor River, about six miles from May's Landing. This furnace was erected in 1802, and has long since been abandoned. Etna Furnace was situated on a tributary of the south branch of Rancocas Creek, two and one-half miles from Medford, and four miles from Taunton, in Burlington County.—Swank's "History of Iron in All Ages." Of these once flourishing concerns scarcely a trace remains. The decline of this district as an iron-producing centre began about 1840, when Scotch foundry iron began to come into this country in considerable quantities. In the early days castings were made directly from the pig metal, and many furnaces produced little iron in the form of pig. The furnaces in South Jersey were unable to meet the severe competition caused by the cheaper Scotch pig, and the rapid decline and total extinction of the iron industry in that locality followed in the early fifties. The Salisbury Furnaces are probably the only ones now on the active list. The companies referred to,

viz., Richardson, Barnum & Co., Canfield, Sterlin & Co., and Holly & Coffing, all operated plants in Litchfield County, Conn., which is in the extreme northwestern portion of the State. The works owned by the last-named firm was located at Chapinville, and here was built the first blast furnace in the Salisbury district. This was about 1762, at which date Ethan Allen was one of the owners of the property. Holly & Coffing also operated a furnace at Mount Riga, which was probably the one from which Boyden obtained his iron. This furnace began operation about 1810, and was abandoned in 1856. Amenia Furnace was located in Dutchess County, N. Y., twenty-four miles east of Poughkeepsie, and not in Connecticut, as Boyden states in his notes. This furnace began operations about 1770, and during the Revolution (there was in operation in connection with it) a small steel works, which was a source of supply for the Continental Army. The steel was probably made from bar iron by the cementation process. Iron from the Salisbury district was hauled by teams to Hudson or Poughkeepsie and thence transported by water. So far as can be learned iron was not sold on commission, at least in the early days. It was usually sold in very small lots, and dealings were direct between producer and consumer. Payments were made in cash or more frequently in long time notes. The Sterling Iron Works were located in Orange County, N. Y., and were in the early days a very important concern. Here was manufactured the huge chain which was stretched across the Hudson in 1778. Part of this chain is still preserved at West Point. Sterling iron was considered for many years one of the best brands for malleable castings, and was in use for this purpose as late as 1861. The Long Mine, from which Boyden obtained some of his ore for packing, was located on this property. Peru and Carthage Furnaces are supposed to have been located near the towns of the same names in New York State, in the Champlain district.

Passing now to the consideration of the *commercial* features and works' practice during the first few years, we find that the foundry which Boyden erected was located at 28 Orange Street, in the rear of his home on Bridge Street.

It gave employment to about sixty moulders. At first, and for much of the experimental work, the iron was melted in a crucible, heated with charcoal or hard coal. Lime was the flux most frequently used and the iron was frequently remelted. This Boyden frequently alludes to in his notes as "refining." Experiments were also made with fluxing with other substances, such as iron ore, sand, clay, glass and sulphur, evidently with the idea of leaving nothing untried. Some of these were obviously forlorn hopes, as in experiment 9 we find the entry: "Delaware, $\frac{1}{8}$ W.; pounded fine with glass, brittle as usual." Boyden's practice seems



to have been to run the iron very high, for he speaks in a number of places of the iron being "sparkling" and "smoky," the latter term presumably indicating incipient oxidation and a very high temperature. Considering these facts it is somewhat remarkable that no mention is made of shrinkage, which does not seem to have troubled the early founders at all. An air furnace was soon built with a capacity of about 1,000 pounds. The fuel was dry pine wood or soft coal, and it is said that eight heats a day were made, starting at 3 A.M. and often not finishing until late in the evening. This furnace was not tapped, the iron being

dipped out in clay-washed ladles, holding from 10 to 12 pounds each. In the notes June 12, 1828, there is a reference to Virginia coal. This coal probably came from the mines in Chesterfield County, near Richmond. Nichols, in his book, "The Story of American Coals," says: "In 1750 the Virginia bituminous mines were opened and worked, on the James River near Richmond; these mines were the first to be opened for the market in the United States. Owned by an English company and competing only with English coal, they enjoyed for some time the exclusive coastwise trade in the Union. In their nature the coals are very dry and gaseous." These mines are not now worked, but were in operation as late as 1842. So-called patent fuel, coal and rosin, came into use in 1831, March 25th. Rosin at this time was very cheap—75 cents to $1.00 a barrel—and so continued until after the Civil War, when it rose rapidly in price. It is said that at one time it reached $68.00 a barrel. Coal tar was used as a substitute.

The first cupola was built in 1832 and used hard coal. This cupola was of the solid bottom type, and consisted of a straight shaft, the upper part of which could be lifted off to allow cleaning and repairs after a heat. The probable reason for this design was the small size of the cupola, which was said to be about 18 inches in diameter. By this arrangement cleaning and repairs to lining were more easily made. The pig and fuel were charged in at the top or at a door near the top. Surrounding the shaft was a large bell-shaped draft stack. An archway through this stack afforded entrance to the charging platform, with ample room between shaft and stack for the men to work. Such a cupola as this could be operated only every other day, as the cinder and unmelted stock required time to cool so that it could be removed and repairs made to lining. The use of cupolas and air furnaces for melting malleable pig was, up to a comparatively recent date, peculiar to this country, it still being the practice in many foreign works to use crucibles.

[*To be concluded.*]

CHEMICAL SECTION.

(Photographic and Microscopic Branch.)

Stated Meeting, Tuesday, June 6, 1899.

AN IMPROVED MICRO-STEREOSCOPIC CAMERA.

BY JOHN G. BAKER,
Member of the Institute.

I have pleasure in showing you this evening a new camera which I have constructed for the purpose of making stereoscopic pictures of small objects.

To accomplish this end has taken much time and a great amount of experimenting. I first fitted up my stereoscopic camera for the purpose, but the result was not at all satisfactory, although I made some very fair negatives with it. The camera proved to be altogether too short, and the lens and object had to be changed from one side to the other, all of which made it very inconvenient. My next attempt is embodied in the instrument I have here this evening for exhibition. It was originally one of Anthony's lantern-slide cameras, which I have altered to what you now see. The shutter used is a 4 x 5 "Victor," made by the Bausch & Lomb Optical Company, of Rochester, N. Y. To the front of this I have fitted an attachment to carry the lens, and also to hold a reflector for properly illuminating the object. In the rear of shutter I have, instead of a lens, a ring, to cut off deflected light that might be caused in its passage through the shutter. The rear end of the camera has been fitted up to receive a 5 x 7 plate-holder, but in such a way that it may be used in two positions, so that each end of the plate may be exposed independently of the other. The plate-holder rests against a partition with an opening in it of a size just sufficient to cover one-half of the plate.

The lenses for very small objects are achromatic objectives that are used in the microscope, but for this work are

changed somewhat, to better answer the requirements. The trouble I found with them for this work was their narrow angle and extremely small depth of focus, and both of these faults had to be remedied before I found it possible to make a satisfactory negative.

I also found that the rays of light, in passing through the lens, had a tendency to fog the plate by coming in contact with flat surfaces, even when these were blacked with the greatest care. I overcame this trouble satisfactorily by dispensing with the flat surface, *i. e.*, by making them on a bevel, with only the sharp edge to reflect the light. To do away with the difficulty arising from the small depth of focus, the only way was to stop down the lens.

Now, as the depth of some objects is very great in proportion to the focal length of the lens, I was compelled to use a very small stop. (I use the word *stop*, as I understand it to mean an aperture placed close as possible to the lens.) The smallest stop I use is $\frac{16}{1000}$ of an inch in diameter, with the edges of the opening made very nearly sharp and carefully blacked. The rear of the lens has also to be guarded, to prevent deflections, which in this work would be very serious.

Of course, the time of exposure requires to be lengthened in proportion to the size of stop; the smallest stop sometimes requires as much as forty-five minutes, and as each exposure must be separately made on the plate, the time will be doubled, making, for the two exposures, ninety minutes.

Now, in regard to the object to be photographed. Let us suppose it to be a small insect. I place it in a bottle containing cyanide of potassium, which soon ends its life; I then set it up on its feet in a position as nearly life-like as I can, on a small piece of opal glass, and, to hold it in position, I fasten each of its feet down by means of wax; this is done by using a very small tool, heated in the flame of a spirit lamp. After the feet are fastened properly, the surplus wax is carefully removed by scraping it away with a fine-pointed knife. The object now is ready for the camera, and upon the pedestal, in front of the lens, the mounted object is made

fast. Now, this pedestal, upon which the mounted object is fastened, has a rack-and-pinion movement, so as to elevate the object to the required height, and has also a ball-and-socket joint on the top, so that the object can be placed in any desired position. The image on the focusing glass is brought in position horizontally, by sliding the lens and board, which can be done by turning the milled head on the top of the camera.

Now, to make the exposure. After everything is ready, I place the object in its best position, and focus as sharply as possible, with the image in its proper place on the ground glass. On the front end of the camera, at the bottom of the pedestal, is a small milled-head screw, which should be turned until it brings up against the shoulder under the camera. This arrangement is for the purpose of permitting the removal of the lens from the object, and its return again to exactly the same place, so that there may be room to change the stops. The reason for doing this is, that after the small stop is in place, it is impossible to see any image whatever on the ground glass.

Now, I fasten front and rear of camera (after the proper stop has been put in place) by means of the clamp screws at the side, and run in the plate-holder until it drops into the first groove, then set the camera in position with the reflector facing a northern sky, and make the first exposure.

After the first exposure is made, the stop is removed and upon the pedestal will be found a graduated circle, divided into parts of 5° each, and also a pointer. This pointer is now to be moved around one of the graduations from left to right, and then the image on the ground glass again placed in position. The stop is put in place, plate-holder is returned and run back as far as possible until it drops into the second groove, and the exposure repeated for the other end of the plate. By revolving the object in the direction just mentioned, the negative itself is made stereoscopic and can be placed in the scope and examined to see if it is perfect.

For objects that are nearly the full size of the picture wanted, I use a pair of wide angle 4 x 5 lenses.

THE NATIONAL EXPORT EXPOSITION

FOR THE ADVANCEMENT OF AMERICAN MANUFACTURES AND THE EXTENSION OF THE EXPORT TRADE.

To be held under the auspices of the Philadelphia Commercial Museum and the Franklin Institute, September 14 to November 30, 1899.

The Franklin Institute will signalize the seventy-fifth year of its life by its active participation in an exposition unique in the commercial history of the United States, in that it will be devoted exclusively to the display of American manufactures and products suited for export. It will be the first conspicuous national event of the kind to mark what thoughtful readers of the signs of the times recognize as the advent of a new era in the manufacturing and commercial history of the country; the period when the first successful steps were taken which resulted in the establishment of a world-wide market for the products of American manufactures.

The exposition will be opened on September 14 and will be closed on November 30, 1899.

In the following the principal facts of interest in connection with the enterprise are briefly set forth :

The first public announcement regarding the National Export Exposition, to be held in Philadelphia next fall, was made at a dinner given at the Art Club, on October 11, 1897, by Daniel Baugh, the Club's President.

Dr. William P. Wilson, Director of the Philadelphia Museums, now the Director-General of the Exposition, in an address at the dinner, stated that the idea of the exposition originated from an exhibition held in Providence, R. I., in June, 1897, for the benefit of the foreign delegates to the meeting of the Advisory Board of the Philadelphia Commercial Museum. This meeting was attended by fifty delegates representing the commercial organizations and governments of sixteen of the Latin-American republics. The exhibition at Providence contained the manufactured products of that city and the State of Rhode Island. The exhibits covered a wide range and were of the greatest interest and value to the visitors from the republics to the south of the United States, who were the guests of the city of Providence nearly three days. Dr. Wilson urged that, in connection with the next meeting of the International Advisory Board of the Museum, it would be advisable to hold in Philadelphia a national exhibition of manufactured goods of the United States especially suitable for export, under the joint auspices of the Philadelphia Commercial Museum and the Franklin Institute.

During the two months following frequent meetings of those interested in the project were held, and the many questions involved in the organization of so great an enterprise were discussed. The Bourse, the Drug Exchange, the Grocers' and Importers' Exchange, the Board of Trade, the Commercial Exchange, the Trades League and other trade and commercial organizations of the city passed resolutions commending the enterprise and pledging their support.

On December 28, 1897, the Philadelphia Exposition Association was incorporated at Harrisburg, under an act which provides for the incorporation

of companies not for profit, organized for the encouragement of the arts and sciences. The first meeting of the incorporators was held on the last day of December, 1898, and organization was effected by the election of Mr. P. A. B. Widener as President and Mr. W. W. Foulkrod and Dr. William Pepper as Vice-Presidents. Committees were appointed, and the project was taken up with enthusiasm and a determination to make the exposition successful.

The agitation which preceded the war with Spain, in the early part of 1898, interfered greatly with the plans for holding the Exposition in the fall of that year, and in February, war with Spain being apparently inevitable, it was decided to postpone the opening of the exposition until the spring of 1899 or the fall of the same year.

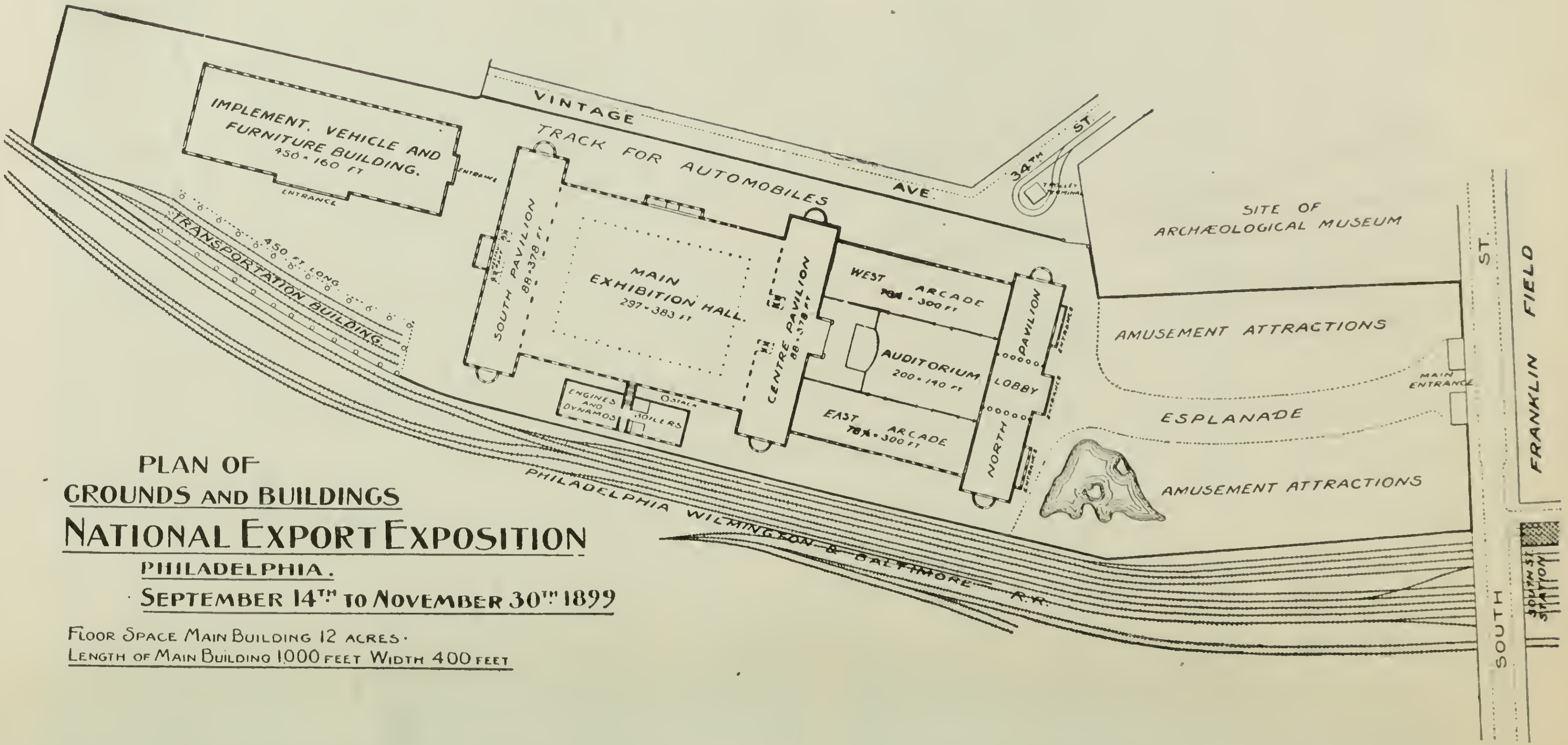
Early in February, 1898, at a meeting of the joint committees of the Philadelphia Exposition Association and the Franklin Institute, the plan for the exposition, as outlined by Mr. William Harper, Chief of the Bureau of Information of the Philadelphia Commercial Museum, was approved. A joint committee of fifteen, composed of five representatives of the Commercial Museum, five of the Franklin Institute, and five named by the Exposition Association, was appointed to organize and generally supervise the plans for the exposition. The committee consists of the following members:

P. A. B. Widener, *Chairman.*	Wm. L. Elkins,	Henry R. Heyl,
	John Birkinbine,	Henry Howson,
James M. Dodge, *First Vice-Chairman.*	Theodore N. Ely,	Sydney L. Wright,
	J. C. Strawbridge,	T. B. Wanamaker,
Wm. P. Wilson, *Second Vice-Chairman.*	George V. Cresson,	F. Lynwood Garrison,
	W. W. Foulkrod,	William Harper.

In the latter part of March, the United States Senate passed a bill appropriating $350,000 in aid of the exposition. The rush of preparations for war with Spain in April of last year in Congress, and the disposition to set aside or cut appropriations for anything but war expenses, prevented the passage of the bill appropriating money in aid of the exposition by the House of Representatives, and after the war broke out its friends concluded that it would be inadvisable to make any further effort to push it.

During the spring of 1898 a loan of $12,000,000 was authorized by the City Councils of Philadelphia, for public improvements, $200,000 of which was set aside for the construction of permanent buildings for the Philadelphia Museums on a site already given to the institution by the city in West Philadelphia. It was proposed by the projectors of the exposition to use the buildings which this money would construct in connection with the exposition. Objection was made by certain influential interests in the city to the loan, and the legality of its issue was forced into the courts.

The outlook in the fall of 1898 was most discouraging, but the exposition management energetically took up the work of inducing the National House of Representatives to pass the appropriation bill of $350,000, which had been favorably acted on by the Senate in the spring. On December 19th the bill passed the House of Representatives after a warm discussion. The officers of the Exposition Association felt that the passage of the appropriation by Con-



PLAN OF
GROUNDS AND BUILDINGS
NATIONAL EXPORT EXPOSITION
PHILADELPHIA.
SEPTEMBER 14TH TO NOVEMBER 30TH 1899

FLOOR SPACE MAIN BUILDING 12 ACRES.
LENGTH OF MAIN BUILDING 1000 FEET WIDTH 400 FEET

Main Building, National Export Exposition—September 14–November 30, 1899.

gress, carrying with it the sanction, encouragement and support of the National Government, was an assurance of success for the exposition, the opening date of which, owing to the delay in action by Congress, had been changed to the autumn of the present year.

Dr. William P. Wilson, Director of the Philadelphia Commercial Museum, was elected Director-General of the Exposition Association, on January 6th, of the present year.

It early became evident that the litigation over the city loan would prevent the holding of the exposition unless City Councils stepped in and by a temporary loan or some other expedient provided the $200,000 which the city had agreed to give. When the emergency was placed before the city authorities, they at once arranged for a temporary loan. The $50,000 appropriated by the State in 1897 left but $50,000 to be raised in other ways to meet the conditions of the Congressional appropriation. This was raised in a few weeks by private subscription. The exposition authorities at once opened offices, awarded the contract for the construction of the Exposition buildings, and set in motion the work of preparing for the first National Exposition of American Manufactures for the Expansion of Export Trade.

The exposition grounds are admirably situated, being easily accessible from all parts of the city both by electric car and steam railroad lines. The grounds are on the west bank of the Schuylkill River, within ten minutes' ride of the City Hall, and comprise a tract of land, fifty-six acres in extent, deeded to the Philadelphia Museums by the city of Philadelphia, and another tract of six acres secured for the uses of the exposition and providing a main entrance from South Street at the northern end of the grounds. Electric cars from every section of the city run on the various streets adjacent to the exposition grounds, and a station of the Pennsylvania Railroad, at which all trains will stop during the exposition, is located within 400 feet of the main entrance. Within a few squares are the passenger stations of the Philadelphia & Reading and Baltimore & Ohio Railroads.

On either side of the broad avenue leading from the South Street entrance to the main buildings, numerous quaint and ornate structures will be devoted to illustrating the life, manners and customs of strange peoples, and to other amusement features of a less instructive but no less entertaining character. Broad avenues surround the grounds on three sides, and the Schuylkill River flows by them on the east. Nearby are the buildings of the University of Pennsylvania, and West Philadelphia, one of the most beautiful of the city's residential sections, stretches to the westward.

The main group of buildings is so constructed as to form one imposing structure about 400 x 950 feet in extreme dimensions, and covering an area of more than eight acres. Five separate buildings enter into this large edifice, which has been constructed largely of brick and steel, and upon lines which the experience of other expositions has proven to be desirable.

The Agricultural Implement and Machinery Building will be devoted exclusively to a comprehensive exhibit of agricultural implements, tools and machinery, in the manufacture of which American factories excel. This building will be 400 feet long and 160 feet wide.

A special structure for exhibits of locomotives and railroad rolling stock, electric cars and equipment for electric railways, is called the Transportation

Building. It is 450 feet long and 75 feet wide, containing four tracks connected with the Pennsylvania Railroad. The length of track available for exhibits of rolling stock will approximate 1,800 feet. Other buildings for special exhibits or lines of trade are advantageously located, and there is every promise that they will prove to be among the leading attractions of the exposition.

Of the five structures comprising the main exhibition buildings, three are permanent, but will only be completed at the present time sufficiently for the purposes of the exposition. These three permanent pavilions will have two stories. They will each be 380 feet long and 90 feet wide. The space between them will be covered by temporary buildings, connected with the pavilions, the whole forming a single harmonious edifice. The permanent buildings will eventually become the home of the Philadelphia Museums.

The temporary building between the northern and central wings will be 300 x 297 feet. It will comprise an auditorium and music hall 250 feet long and 140 feet wide, with arcades for exhibits on each side, 300 feet long and 70 feet wide. Between the central and southern pavilions there is an immense area for exhibits 383 x 297 feet in size, covered by a wide expanse of roof supported by trusses resting on columns. The exhibition spaces on the first floor of the pavilions will open into the main hall through wide arches, so that the entire area of 167,200 square feet, 563 x 297 feet in dimensions, will be practically a single open space.

East of the central exhibition hall and connected with it is the exposition power plant, 190 x 58 feet in size. It is adjacent to the Pennsylvania Railroad tracks, affording excellent facilities for handling heavy exhibits. Engines, pumps, air-compressors and dynamos are located in one end of the power-house, and in the other the boilers.

The entrance to the main buildings is through a broad lobby 60 x 90 feet in size, in the centre of the northernmost wing. Handsome columns and decorations and groups of statuary will embellish the lobby. To the right and left, wide aisles lead through the exhibition spaces of the north wing, turning at right angles through the arcades on each side of the auditorium into the central exhibition hall and its wings.

In the auditorium, which will have a seating capacity for more than 5,000 persons, the sessions of the International Commercial Congress will be held, as well as the conventions of various trade and business organizations which have arranged to hold meetings during the exposition.

There are staircases in each wing of the main building leading to the second floor, and it is contemplated that in addition electric and hydraulic elevators and moving staircases will be provided in the form of exhibits. The second floor of the north wing will be occupied by the administration officers of the exposition. In the central and south wings, the upper floors will be given up to exhibits.

A total area of 200,000 square feet of space is available in the main buildings for exhibits. This, with the space provided for in the special buildings, will give American manufacturers ample facilities for a great display.

Running from the main floor of the exhibition hall will be a short flight of stairs rising to the level of the roof of the power-house. This roof will be flat, surrounded by an ornamental railing, and is designed to be used as a

plaza from which visitors may obtain a view of the river, and that portion of the exposition grounds lying east of the railroad track, where windmills, traction engines and all kinds of machinery and farm implements such as are not suited for exhibition in the implement building will be displayed. This space is also available for buildings for special exhibits and for machinery which requires a large space to show it in operation.

From the top of the power-house a commodious bridge will lead across the tracks of the Pennsylvania Railroad, and at the further end a flight of stairs will permit access to the eastern part of the grounds without crossing on the track level.

While the exposition has in view a most practical purpose, there was not, in the planning of the buildings, any idea of completely subserving the beautiful and the artistic to its practical end. On the contrary, the ornamentation and decorations of the structures, though of the temporary character which must of necessity be used in exposition buildings, will be most attractive. Out of a composition, the basis of which is plaster and papier-maché, more durable than the "staff" which made the buildings of the Columbian exposition so beautiful to look upon, have been formed columns with capitals as beautiful as though carved in white marble. Cornices and friezes, panels and screens, the designs of skilled sculptors, aid in giving the buildings rare architectural attraction.

Above the main entrance, a large pediment contains a group of thirteen figures, representing Commerce. Other pediments typify the four continents. Numerous groups of graceful figures allegorical of Transportation, Navigation, Labor, Electricity, etc., rest on pedestals beside the pediments, and over the main entrance there is a large quadrager—a chariot drawn by four horses, carrying a beautiful figure typifying Progress.

One of the most conspicuous events to take place in connection with the exposition will be the International Industrial and Commercial Congress, which will assemble in Philadelphia, beginning with October 10th. A number of foreign governments have accepted the invitation to send official envoys, and many foreign cities, and almost every city of the United States and Canada with a population over 10,000 will be represented by delegates from their Boards of Trade, Chambers of Commerce, etc.

Of special interest to the members of the Franklin Institute will be the ceremonies in commemoration of the seventy-fifth anniversary of the society, which will be held in one of the exposition buildings. The arrangements for this event contemplate a series of commemorative meetings, beginning Monday evening, October 2d, and occupying the entire week. Saturday evening, October 7th, will be Institute Day, and the occasion will be devoted to a general commemorative meeting of the Institute. The evenings of the week will be occupied successively by the Sections in the order of seniority, beginning with the Chemical Section. A feature of these commemorative meetings will be an address or addresses by distinguished specialists. The speakers on Institute Day will be Dr. Robt. H. Thurston and Rear Admiral Geo. W. Melville, U. S. N. For the convenience of members, it is contemplated to install a reading room and general headquarters, where non-resident members will find it convenient to receive mail, and make business or social appointments. W.

NOTES AND COMMENTS.

A NEW POWER IN PHOTOGRAPHY.

Just when to stop the development of the photographic negative on a gelatino-bromide plate has always been more or less of a problem even to the expert; and as over- is more easily corrected than under-development, it has been the practice, when in doubt, to carry it beyond what was known to be necessary, trusting to reduction to bring the image back to the required density.

For this purpose various methods or reducing agents have been employed, but hitherto they have all had one fault in common—the altering of the values, tonality, or gradation, the most important feature of a negative. This they do in consequence of the fact, hitherto supposed to be inevitable, that reduction goes on equally all over the plate, as much being removed from the delicate detail, in what will be the shadows, as from the denser deposit of the half-lights and lights, resulting in negatives that give prints of the white and black or "soot and whitewash" variety.

Recently, however, the brothers Lumière, to whom photography is already much indebted, have given to photographers a new power in the shape of ammonium persulphate, a solution of which has the property of attacking only, or at least first, the higher and half-lights without touching the weaker deposits in the shadows, thus enabling them to reduce contrasts and secure such values or gradation as they may desire.

It will be evident that with one of the older reducing agents that reduce equally all over the plate, and the new agent which acts only on the denser parts of the image, the photographer may with confidence develop to any degree of opacity, knowing that he has the power, by reduction, to produce any degree of gradation that he may desire.

Hardly less of a problem, especially to beginners, has been how to secure correct exposure; and according to at least one expert, the solution is to be found in ammonium persulphate. It is well known that over-exposure tends to flatness. The negatives may have all necessary detail, but the lights and half-lights are so translucent as to give only weak, flat prints. If, however, ammonium persulphate in conjunction with a bromide be added to the ordinary developing solution, any degree of contrast may be obtained, even to simple white and black, the degree being in proportion to the quantity of persulphate added. For this purpose W. B. Bolton recommends a solution of ammonium persulphate 25 grains and ammonium bromide 5 grains in 1 ounce of water, and a few drops added to the developer. The action will be slower, and the degree of contrast greater, in proportion to the quantity of solution added; but a few experiments will show just what that quantity should be for any reasonable amount of over-exposure.

It may be well to add that the new reducer is not the acid or hydrogen-sulphate, NH_4HSO_4, sometimes called the persulphate, but the true persulphate, NH_4SO_4, said to be produced by electrolysis from the hydrogen-sulphate, thus $NH_4HSO_4 = NH_4SO_4 + H$, the atom of hydrogen being eliminated and the persalt formed at the negative electrode. W.

INFLUENCE OF ANTIMONY IN BRASS.

In a paper before the American Institute of Mining Engineers, Mr. E. S. Sperry has pointed out that the occurrence of cracks during the rolling of brass is due, in some cases at least, to the presence of impurities in the copper of the alloy. In certain investigations made by this author, he added to a brass composition made of 60 per cent. of purest lake copper and 40 per cent. zinc, quantities of antimony varying from 0·01 per cent. to 0·65 per cent., and tested the behavior of the alloys thus obtained in the rolling mill. He found that when the percentage of antimony reached as much as 0·02 per cent. the fracture of the rolled metal indicated its presence. It would appear, therefore, that the presence of antimony in electrolytic copper, the author thinks, is the cause of the unreliability of brass which requires to be rolled. W.

ELECTROTYPES OF IRON.

It has been disclosed that the Austrian and Russian Governments print their bank-notes from steel-faced electrotypes made by the electrolytic deposition of iron from a bath prepared according to the formula of Klein (ferrous and magnesium sulphates) under special conditions of temperature and current-density. This latter must be very small, inasmuch as a plate only 2 millimeters in thickness requires one and a half months for its deposition.

The thin iron electrotypes prepared according to this method are backed in the usual way (with stereotype metal?).

According to Herr Haber, in the *Zeit. f. Elektrochemie*, the advantage of plates prepared in this way lies in the fineness and hardness of the metal, which is first deposited, and in the delicacy of the copy of the original which is thus obtained.

The usual plan of preparing such printing plates—so-called steel-faced plates—is to obtain first a copper electrotype of the original, and then to face this with iron by suspending it at the cathode in the above-named electrolytic bath of Klein, or its analogue. The author declares, however, that the printing results obtained are not nearly so good as when the first method is employed.

A serious disadvantage of the all-steel electrotypes, however, is that they can only be renewed by repeating the entire process of electrotyping, while the iron-faced copper plates can have their faces renewed in a few minutes. W.

THE DRYING OF LINSEED OIL.

Lippert has made some interesting experiments on the absorption of oxygen by thin films of linseed oil on sheet iron.

He finds that raw linseed oil increases in weight slowly for three days, more quickly on the fourth day, and becomes dry on the seventh. The total gain is found to agree closely with that given by Mulder, namely, 12·4 per cent.

Linseed oil, strongly boiled without driers, dries more slowly than raw oil, and is more difficult to manipulate owing to its great viscosity, but eventually it absorbs within 2 per cent. of the oxygen taken up by the raw product. Ordinary boiled oils cannot be compared with raw linseed oil without taking note of the drier they contain. W.

FERMENTATION WITHOUT LIVING CELLS.

As a result of the investigations of Professor Büchner, of Tübingen, another of the fetiches of old chemistry is destroyed, namely, that living cells are necessary to fermentation. Professor Büchner, according to *Science*, grinds yeast with quartz sand in order to disrupt the cells, and submits the moist mass to a pressure of 500 atmospheres. The liquid contents of the cells are entirely removed and the cells totally disrupted. The filtered liquid is of a clear or slightly opalescent, yellowish color, retains the odor of yeast, contains considerable carbon dioxide and some albumen. Most interesting is the behavior of the yeast juice towards sugars, fermentation being set up much more quickly than by yeast, and proceeding much faster. The gas evolved is almost pure carbon dioxide. When carefully dried at a low temperature, the fermenting principle is not destroyed, and it is possible that, when desiccated, the activity of the ferments may be preserved indefinitely. W.

A SIMPLE MEANS OF OBTAINING A HIGH VACUUM.

The use of liquid hydrogen has been proposed by Professor Dewar for the production of very high vacuo. If the end of a closed tube containing air is immersed in liquid hydrogen, the contents of the tube are quickly condensed to solid air, and if the portion of the tube from which the air has thus been removed is sealed with a blow-pipe, a vacuum is obtained so high that it will scarcely allow an electric discharge to pass. This condensation is accomplished almost instantly, the required time of immersion never being more than a minute. This gives a simple means of obtaining the high vacuum necessary in Crookes tubes, and might possibly be on a large scale sufficiently economical for use in incandescent lamp works. W.

ADDITIONS TO MEMBERSHIP.

April 1 to June 30, 1899.

The following persons have been elected and qualified as members of the Franklin Institute during the three months beginning April 1st and ending June 30, 1899:

Agassiz, A., Cambridge, Mass.

Alteneder, John, 609 Green Street, Philadelphia, Pa., Medical Illustrator.

Ashmead, Frank M., 11 Pike Street, Pittsburgh, Pa., Civil Engineer.

Bacon, Henry Douglas, 4223 Girard Avenue, Philadelphia, Pa., Marine Architect.

Baldwin, Ward, University of Cincinnati, Cincinnati, O., Professor of Civil Engineering.

Binder, Richard L., 808 North Seventh Street, Philadelphia, Pa., Salesman.

Bonner, James B., 502 Harrison Building, Philadelphia, Pa., Sales Agent Carnegie Steel Co.

BRODHEAD, CALVIN E., Northeast corner Fourteenth and Bushkill Streets, Easton, Pa., Engineer and Contractor.

BUCHHOLZ, CHAS. W., 21 Cortlandt Street, New York, N. Y., Civil Engineer.

BURGDORFF, THEODORE F., care Navy Pay Office, U. S. S "Monadnock," San Francisco, Cal., Chief Engineer U. S. Navy.

BURGWYN, C. P. E., 818 Main Street, Richmond, Va., Consulting Engineer.

BURR, WM. H., Columbia University, New York, N. Y., Professor of Civil Engineering.

CARNEY, JAMES A., Beardstown, Ill., Master Mechanic St. Louis Division C. B. & Q. R. R.

CARR, ALBERT, 19 Amherst Street, East Orange, N. J., Civil Engineer.

CARTER, EDWARD C., care C. & N. W. Ry., Chicago., Ill., Assistant Engineer C. & N. W. Ry.

CHALMERS, W. J., Fulton and Union Streets, Chicago, Ill., President Fraser & Chalmers Co.

COFFIN, JOEL S., care Galena Oil Co., Franklin, Pa., Mechanical Expert.

CONVERSE, W. H., Chattanooga, Tenn., President Converse Bridge Co.

COPPEE, H. St. L., Greenville, Miss., U. S. Assistant Engineer.

DAVIDSON, GEO. M., care C. & N. W. Ry. Co., Chicago, Ill., Chemist and Engineer of Tests.

DAVISON, B. FRANKLIN, 718 Sansom Street, Philadelphia, Pa., Metal Worker and Electroplater.

DEANE, CHAS. P., Springfield, Mass., Mechanical Engineer.

DELANO, WARREN, 1 Broadway, New York, N. Y., Coal Operator.

DICKERSON, WALTER H., care Edison Laboratory, Orange, N. J., Mechanical Engineer.

DIDIER, PAUL, Allegheny City, Pa., Chief Engineer Pittsburg & Western R. R.

d'INVILLIERS, CAMILLE S., Altoona, Pa., Civil Engineer.

DIVEN, J. M., Elmira, N. Y., Superintendent Water Works.

DOANE, SAMUEL E., Hotel Proctor, Marlboro, Mass., Electrical Engineer.

DOUGLAS, BENJAMIN, Detroit, Mich., Bridge Engineer Michigan Central R. R.

DRAKE, W. A., Prescott, Ariz., Chief Engineer S. F. P. & P. Ry. Co.

DUNCKLEE, JNO. B., 601 Eighteenth Street, Washington, D. C., Civil Engineer.

ELDRIDGE, G. M., Defiance, O., Superintendent Defiance Water Co.

FELTON, SAMUEL M., Cincinnati, O., President and Receiver C. N. O. & T. R. R.

FITCH, MAX B., Magdelena, Sorocco Co., N. M., Superintendent Smelting Works.

FITZGERALD, FRANCIS J., care Carborundum Co., Niagara Falls, N. Y., Chemist.

FOLSOM, EDSON F., 1418 Park Avenue, Indianapolis, Ind., Mechanical Engineer.

FORBES, JOHN S., 220 South Fifth Street, Philadelphia, Pa., Mechanical Engineer.

FORD, PORTER DWIGHT, Long Island City, N. Y., Chief Engineer Long Island R. R. Co.

FRIES, C. N. D., 421 Chestnut Street, Philadelphia, Pa., Telegrapher.

GIBSON, JAMES E., care American Pipe Manufacturing Co., Fidelity Building, Philadelphia, Pa., Mechanical Engineer.

GODSHALL, L. D., Ph.D., Nelson, B. C., Canada, Metallurgist.

GREENE, EDWARD A., 141 Broadway, New York, N. Y., Civil Engineer.

HALL, CHARLES M., Niagara Falls, N. Y., Chemist and Electrical Engineer.

HALL, EDWIN, 3220 Powelton Avenue, Philadelphia, Pa., Contracting Engineer.

HALL, JULIEN A., Morotock, Va., Civil Engineer.

HAMMER, WM. J., Havemeyer Building, 26 Cortlandt Street, New York, N. Y., Consulting Electrical Engineer.

HAMMOND, GEORGE W., Yarmouthville, Me., Fibre Manufacturer.

HARDING, H., 2016 Quinlan Avenue, Birmingham, Ala., Civil Engineer.

HARRIS, J. F. W., Terre Haute, Ind., Superintendent Mechanical Engineering Department Rose Polytechnic Institute.

HARROD, B. M., 1637 Foucher Street, New Orleans, La., Civil Engineer.

HASCHKA, FERDINAND T., 1013 Spruce Street, Philadelphia, Pa., Watchmaker.

HENDLEY, FRANK P., 514 North Fifth Street, Philadelphia, Pa., Wholesale Grocer.

HERMANY, CHARLES, 1216 Fourth Avenue, Louisville, Ky., Civil Engineer.

HERRICK, ALBERT B., 120 Liberty Street, New York, N. Y., Electrical Engineer.

HEWITT, CHARLES M., 925 Monadnock Building, Chicago, Ill., Brass Manufacturer.

HOFF, OLAFF, 230 Lumber Exchange, Minneapolis, Minn., Civil Engineer.

HULST, NELSON P., Milwaukee, Wis., Manager of Mines.

JAEGER, A. H., 2236 North Sixth Street, Philadelphia, Pa., Translator.

JOHNSON, J. E., Longdale, Alleghany Co., Va., Blast Furnace Manager.

JUDSON, C. A., Sandusky, O., Civil Engineer.

JUST, GEO. A., 128 West Forty-second Street, New York, N. Y., Consulting Engineer.

KEYSER, NAAMEN H., D.D.S., 33 Church Lane, Germantown, Pa., Dentist.

KIERSTED, WYNKOOP, 58 Water Works Building, Kansas City, Mo., Civil Engineer.

KNIGHT, ALBERT B., P. O. Box 211, Butte, Montana, Mining Engineer.

LANGCLOTH, J., P. O. Box 957, New York, President American Metal Company

LASSIG, M., 1784 Deming Place, Chicago, Ill., Bridge Builder.

LEWIS, JAMES F., 1328 Monadnock Building, Chicago, Ill., Mining Machinery.

LOVEJOY, J. R., 812 Union Street, Schenectady, N. Y., General Superintendent Supply Department General Electric Company.

MAGRUDER, CHAS. A., 4042 Walnut Street, Philadelphia, Pa., Electrical Engineer.

MAISCH, FRED. D., 1420 Poplar Street, Philadelphia, Pa., Photographer.

MARSHALL, J. T., Metuchen, N. J., Electrical Engineer.

MAURO, PHILIP, 620 F Street, Washington, D. C., Attorney-at-Law.

McMeekin, Chas. W., Libby, Montana, Consulting Engineer.

McVean, John J., 71 State Street, Grand Rapids, Mich., Chief Engineer C. & W. M. Ry.

Miller, A. M., 2728 Pennsylvania Avenue, Washington, D. C., Lieutenant-Colonel Corps of Engineers.

Morse, Willard S., Monterey, Mexico, Smelter and Refiner of Metals.

Neiler, Samuel G., 1409 Manhattan Building, Chicago, Ill., Consulting Electrical and Mechanical Engineer.

Parsons, Geo. Wellman, Steelton, Pa., Superintendent Frog, Signal and Switch Department the Pennsylvania Steel Co.

Patterson, Horace H., 3720 Locust Street, Philadelphia, Pa., Mechanical Engineer.

Post, Walter A., Newport News, Va., General Superintendent Newport News Ship and Dry Dock Co.

Radford, Geo. Reginald, 314 Walnut Street, Philadelphia, Pa., Agent C. M. Dodson Coal Co.

Reeser, Otto, 500 North Twelfth Street, Philadelphia, Pa., Machinist.

Saunders, W. F., 26 Cortlandt Street, New York, N. Y., Engineer.

See, James W., Opera House, Hamilton, O., Mechanical Engineer.

Shanks, Thomas P., Little Hickman, Ky., U. S. Assistant Engineer.

Slater, A. B., Jr., Providence, R. I., Engineer Providence Gas Co.

Smith, H. S. S., Princeton University, Princeton, N. J., Professor of Applied Mechanics.

Smith, T. Guilford, Buffalo, N. Y., Civil Engineer.

Spencer, Chas. J., 1529 Wallace Street, Buffalo, N. Y., Electrical Engineer.

Stanton, Rob't Brewster, Sewickley, Pa., Civil and Mining Engineer.

Steinmetz, Chas. P., 243 Liberty Street, Schenectady, N. Y., Electrician.

Steinmetz, Joseph Allison, Drexel Building, Philadelphia, Pa., Aluminum Products.

Stiles, Norman C., Watertown, N. Y.

Stirling, J. Carolus, 145 Woodland Street, Hartford, Conn., Treasurer of Pratt & Whitney Co.

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JOURNAL

OF THE

FRANKLIN INSTITUTE

OF THE STATE OF PENNSYLVANIA,

FOR THE PROMOTION OF THE MECHANIC ARTS.

VOL. CXLVIII, No. 3. 74TH YEAR. SEPTEMBER, 1899

ELECTRICAL SECTION.

Special Meeting, June 10, 1899.

WATER-POWER ELECTRICAL PLANTS IN THE UNITED STATES.

By B. C. WASHINGTON, JR.

In presenting to you to-night a paper on "Water-Power Electric Plants in the United States," it is my purpose to show you the great importance of the development of this great branch of our natural resources, and to describe and illustrate a few of the more important plants, and give you the benefit of some statistics gathered by personal correspondence with those directly in charge of over 300 plants. The illustrations cover almost the entire field, and show the perfection attained by the unparalleled genius of American minds in the production of suitable machinery to meet all the different requirements imposed, no matter what are the conditions.

For many centuries man has patiently and earnestly sought to control the vast powers of nature, so that they

shall do his bidding. Human genius has triumphed, and now on the eve of the twentieth century an enlightened world gazes in wonder and admiration while Americans harness the power of their greatest rivers, convert this power into electricity and transmit it with commercial success to distant mining or manufacturing centers.

The application of water as a power for driving mechanical devices is supposed to have been attempted in Rome, about the time of Augustus, 63 B.C. to A.D. 14. During the succeeding centuries various machines have been originated for the utilization of water-power, and recent years have witnessed a most rapid and wonderful progress in their development. The old power-wasting water-wheels of various types have been superseded by turbines for ordinary heads of water, and wheels of the Pelton and Impulse types for extraordinary heads.

The first transmission of electrical power for industrial purposes was accomplished in 1878, at Sermaize, a short distance from Paris, France. The dynamos in this instance were driven by steam engines. Shortly after this demonstration of the practicability of the transmission of electricity, followed the application of water-wheels for driving dynamos.

In the United States there are now nearly 500 electric plants operated by water-power, or water-power and steam combined. Notwithstanding this, there are many hundreds of fine water-powers totally undeveloped, or only partially developed, which would yield handsome returns on the cost of improving them and utilizing their power for the generation of electricity. Some are more favorably situated than others, but nearly all of them of any commercial importance can be developed.

The immense advantages of electrical development are its cheapness, the flexibility and divisibility of the power, and the ease with which it can be transmitted from the point of generation to the point of utilization.

As a power producer the stream must be reasonably steady in the quantity of its discharge. This can be readily determined by pursuing the accurate methods employed in stream measurements by the government hydrographers.

Having ascertained the fall, and the quantity of discharge, the amount of power that is available is readily determined. The next problem is the disposition to be made of the power when it is developed. This is often known in advance, but in some cases the power owners are confronted with many difficulties. The location of the power may not be suitable for a manufacturing site, and should it be desirable to transmit the power to manufacturing centers, existing power and light companies may own franchises which give them exclusive control of the territory. It is not always an easy matter to induce manufacturers owning expensive steam plants to discard them and substitute electricity, although they know it to be cheaper, more reliable, cleaner and generally safer than steam.

The problem of water-power development is, as a matter of course, one of dollars and cents, and the main question is, will the income be sufficient to pay a reasonable per cent. on the investment, over and above general and operating expenses, taxes, maintenance and repairs and depreciation? This question is referred properly to the engineers in charge of the prospective development. The development naturally divides itself between the expert in hydraulics and the expert in electricity. To these experts it remains to solve all the varied and sometimes exceedingly difficult problems that are presented. The machinery for these plants must be constructed to suit the conditions imposed, and the conditions are the unknown quantities which enter the equations and are only solved by experienced engineers. The up-to-date manufacturers of water-wheels and electrical apparatus employ the best of engineering talent, and this talent is at the disposal of those contemplating the construction of water-power electric plants. Upon the engineers devolve the selection of the site for the dam and power-house, and the preparation of plans and specifications for their building and equipment. The kind of dam and its location depend largely on the character of the stream, the shape and geological structure of its sides and bottom, and also the topographic features above and below the prospective site. Of course, dams are

constructed to withstand extraordinary freshets and injury from ice and floating *débris* of all kinds, and of a height that will not cause disastrous results to surrounding property from overflow or backwater. Proper protection is afforded canals, waterways and penstocks leading to the power-house, and ample provision made to keep sand and other detritus from entering the water-wheels. Local conditions are also important factors in the selection of the site for the power-house. When practicable, it is located as near as possible to the source of power, so that the expense for canals, flumes and penstocks will be reduced to a minimum.

The plan of the power-house depends largely upon the style of water-wheel used and the method adopted for delivering the water to the wheels and carrying away the discharge water, the connections between the water-wheels and generators, and whether the plant has additional or reserve steam power. The building and foundations for wheels and generators must meet every requirement of strength and solidity. The entire construction must also be fire-proof. No power-house is complete without a travelling crane.

Recent construction shows a very commendable desire on the part of engineers to standardize the building plans and machinery as far as practicable. The location of switchboards, transformers and outgoing wires are matters of detail for the engineers to decide. Currents of high voltage require extraordinary care in the placing and insulation of transmission wires, and the best methods in use will be shown later.

There are at present two styles of water-wheels in general use in the United States for dynamo driving, viz.: turbines and impulse wheels. As a rule, the use of turbines of the vertical and the horizontal style is confined to powers of ordinary head, where the water is plentiful. The impulse wheels are a necessity under opposite conditions. There are, perhaps, some exceptions to this statement, but I do not think them sufficiently numerous nor important to be cited at this time.

Both styles of water-wheels require the use of water-wheel governors, and this is especially true of plants where there is a variable load on the generators.

There are many different devices on the market for governing water-wheels. Reports from the plants show that the field is almost entirely covered by three governors, viz.: the Replogle, the Lombard and the Geissler. They give remarkably close government under all working conditions, and guard against excessive speed or racing in case of the whole load going suddenly off, as in the case of circuits opening. Only last year you had an able paper read to you on the government of water-wheels, so that there remains little for me to say in connection with this subject, except that Mr. Replogle has perfected and brought out a new governor. It is well known that the voltage drops at the receiving station as the load increases on the line of long-distance transmission plants. This latest governor of Replogle's can be so adjusted as to automatically increase the speed of water-wheels as the load increases, thereby holding the voltage constant at the distant end of the line. In making this advantage possible, he has not destroyed the principle that holds all the gates at several wheels to the same opening, where a number of units are running in parallel.

The kind of generators used, of course, depends largely on the length of the transmission line and the work required. For all long-distance transmission, alternating current generators are used. The voltage of the current generated is raised by transformers and carried at high voltage to the receiving station, and there stepped down by lowering transformers and utilized for light and power purposes.

The pole lines follow roads when practicable, and when run across country the timber is cleared from both sides of the line, so that uprooted trees and limbs broken by storms will fall clear of the line. The poles and cross-arms are of selected timber. The poles are firmly planted and securely braced at curves. Special high voltage insulators are used. The transmission wires are bare copper, the high voltage permitting the economical use of light wires. The wires are spiralled, to prevent induction if telegraph or telephone wires are strung on the same poles.

With this brief general outline of some of the features kindred to water-power transmission plants, I will briefly describe some of the large transmission plants in successful operation in the United States, and attempt, figuratively speaking, to take you through them by means of illustrating the machinery they have in use at the same time it is described. You will kindly bear in mind that some of the ground has been covered by descriptive articles published in technical papers. Nevertheless, it is necessary to make use of some of this material in order to bring out all of the different types of machinery used, the various methods employed in connecting water-wheels and dynamos, and the applications of the power for various mechanical purposes.

THE FOLSOM-SACRAMENTO ELECTRIC TRANSMISSION PLANT.

For data relative to the Folsom-Sacramento electric-power transmission I am largely indebted to Mr. George P. Low and the Sacramento Electric, Gas and Railway Company.

The water-power of the American River is utilized for driving the generators. The various forks of this river rise in the Sierra Nevada Mountains near Lake Tahoe. The water supply of the river presents some peculiar features not found elsewhere, in that the flow of water is derived from new sources at all seasons of the year. In the late spring and summer months the melting snows in the mountains "bridge" over the "dry season," and in the fall, just as this source of supply is on the wane, the rainy season sets in. The foundation of the dam was begun in 1886 by the Natoma Water and Mining Company, and on this foundation, in 1888, the transmission company began the work of completing the dam. The river is confined for many miles by high granite bluffs, and where the dam is erected they form a natural point for the building of such a structure.

The dam contains 30,000 cubic yards of masonry and the headworks about 15,000 cubic yards. The storage capacity of the dam is about 13,000,000 cubic yards of water. The shutter is a trussed timber platform, which

rests in a masonry recess running longitudinally along the top of the center of the dam. When lowered, it is secure from damage by floating *débris.* The shutter is operated by five hydraulic rams.

The sand gates, each covering an opening 5 by 6 feet through the wing dam, are located at the end of the dam to prevent sand or gravel from passing into the canal and causing injury to the water-wheels. The bottom of each gate is 8 feet below the bottom of the canal, and a short distance further down the stream a wall 8 feet high is built directly across the canal. The inlets to three of the gates are tunnel-like openings covering the width of the canal. As the openings are 8 feet below the bottom level of the canal, the water has sufficient flow to remove and discharge heavy substances into the river below. The dam and head-works are built of granite taken from the cliffs on each side of the river. The west bank of the canal is built of granite part of the distance and of earth the remaining distance. The headgates are operated by hydraulic rams.

Two thousand feet down the canal a drop of 7·33 feet occurs. At this point is located the State power-house. This building extends across the canal. The building is 160 feet long, 60 feet wide and 60 feet high, and is built of heavy granite masonry. Six special 87-inch Leffel turbine water-wheels with vertical shafts, geared to bevel pinions to a horizontal shaft overhead, deliver power for electrical and other purposes. About 800 horse-power is now utilized. Without waste the water flows on in a canal built by the Folsom Water-Power Company. At the terminal of the canal is a forebay 150 feet long, 100 feet wide and 12 to 15 feet deep, constructed with ample provision for cleaning out silt and preventing it from reaching the turbines. The hydraulic machinery was all made and furnished by The S. Morgan Smith Company, of York, Pa., and consists of four pairs of 30-inch McCormick horizontal turbines of 1,260 horse-power each. The wheels run under a head of 55 feet at 300 revolutions per minute, and are directly connected by couplings to the armature shafts of the generators. The inlet pipes are 8 feet in diameter, and made

of $\frac{3}{8}$-inch steel. Double draft tubes are provided for each set of wheels. Between the four large wheels is the special wheel for driving the exciters. The wheels are made of phosphor-bronze, and each pair is furnished with steel fly-wheels 10 feet in diameter, weighing 10,000 pounds. To each of these four double turbines is directly coupled a 750 kilowatt 3-phase generator built by the General Electric Company. These were the largest constructed up to that time (1888). They are 8 feet $8\frac{1}{2}$ inches high, cover a floor area of 11 feet by 8 feet 8 inches, and weigh nearly 29 tons each. The generators have twenty-four poles, and deliver 3-phase current at 60 cycles per second at 800 volts. There are two four-pole 500-volt exciters, of 30 kilowatts capacity each, either of which can be used to excite all four generators. The generators are carefully insulated from, and securely bolted to, solid masonry.

The current is led through a simple switching board to the bank of step-up transformers on the upper floor of the building. These transformers are of the air-blast type, manufactured by the General Electric Company, and have a capacity of 250 kilowatts each.

The switching board is of Tennessee marble. The two outside panels control the four generators. The center panel contains the synchronizing indicator lamps, the exciter instruments, and main line switches. The generator panels are provided with voltmeters, current indicators and pressure regulators.

Both the primary and secondary coils of all the step-up transformers are worked in parallel, taking current at 800 volts from the generators and delivering it to the lines at a potential of 11,000 volts. Each generator is provided with a separate and distinct circuit from the power-house to Sacramento, and can be worked singly or in parallel. Sturtevant blowers, both at Folsom and Sacramento, each operated by a 2 kilowatt induction motor, furnish air for cooling the transformers when the load is sufficient to cause their heating.

A double-pole line, 22·75 miles long, follows the country road and Sacramento Valley Railroad. The poles are of

cedar, 40 feet long, 12 inches at the top, and 16 at the butt, and are set 6 feet in the ground, 52 to the mile. The cross-arms are braced with angle irons, and are 4 inches x 4 inches in cross-section and 7 feet long. The transmission circuits are supported on double-petticoat porcelain insulators tested to withstand a potential of 25,000 volts. The pole lines each support six No. 1 B. & S. bare copper wires, which effect the transmission at an estimated loss of 10 per cent. at full load. A telephone line is carried on one set of poles. The line is transposed every five poles.

The distributing station is an imposing and substantial two-story fire-proof brick building, and, in addition to the offices of the company, it contains on the ground floor the motor and generator room, in which are located three 3-phase synchronous motors, the electric railway generators, and arc-lighting dynamos. The transmission circuits are led direct from the pole lines to the step-down transformer chamber, in which are located the various transformer equipments.

Three large 250 kilowatt synchronous motors are supplied with energy from 125 kilowatt transformers, which deliver current at 500 volts. The other transformers step-down to 125 volts, the current being distributed over the city on a four-wire system, consisting of three wires for the 3-phase current and a fourth or neutral wire.

The incandescent lighting service is rendered by extensions made between either of the three wires and the neutral, proper care being taken to keep the circuits balanced within reasonable limits. The power service is rendered directly from the 3-phase wiring. Large motors are operated from 500 volt 3-phase wiring; the 125 and 250 volt 4-wire system is used for small motor work and incandescent lighting.

It is hardly necessary to give a recapitulation of the electrical equipment of this very extensive plant, and lack of time has prevented my giving you a more complete description of some of the electrical machinery. The plant was started on July 14, 1895, and has been in successful operation day and night ever since, with the exception of some

weeks, when low water caused a partial shut-down. The useful work performed by this plant can be summed up as follows: It has furnished current for 525 arc lamps, 22,000 incandescent lamps, 1,400 horse-power of motors, and 35 motor cars operating 24·5 miles of single-track and 17 miles of double-track electric railway.

NEWCASTLE-SACRAMENTO TRANSMISSION PLANT.

The Newcastle-Sacramento Transmission Plant is an interesting plant, illustrative of the utilization of a high head of water. This plant is on the Sierra Nevada divide, northwest of Sacramento. At various points on the canal system of the South Yuba Water Company are "drops" or sudden falls. The most important "drop" is one of 464 feet, of which 400 feet is utilized for driving the power plant of the Central California Electric Company.

The water is carried from a reservoir to the power-house, a distance of 6,400 feet, in a 24-inch pipe of riveted sheet steel. The pipe is buried two feet under ground. At the power-house the pipe forks, in a heavy cast-iron Y, into two 15-inch pipes of No. 6 steel, running to the Ys on the Pelton water-wheels. These wheels are of the double pattern, two 48-inch wheels being direct-connected to each of the two 400 kilowatt generators. No automatic water-wheel governors are used, the regulation being effected manually by the switchboard attendant. Not very close attention is required, as the plant runs under a load so evenly laid on or taken off that every change can be anticipated, and even a waste of water avoided. The Westinghouse Electric and Manufacturing Company supplied the entire electrical equipment of this plant, consisting of two alternating current 2-phase generators, two exciters, generator switchboard, step-up transformers, 2-phase 500 volts to 3-phase 15,000 volts, 28 miles 3-phase 15,000 volts transmission line, 15,000 volts receiving switchboard, reducing transformers, 3-phase 15,000 volts to 2-phase 2,000 volts, distribution switchboard, 2,000 volt circuits, and transformers for motors and lights.

The two 400 kilowatt generators are of the inwardly pro-

jecting field and revolving armature type, and run at a speed of 400 revolutions per minute. They generate 2-phase alternating current of 7,200 alternations per minute at 500 volts. The machines are excited by two 15 kilowatt 125 volt exciters, driven by separate Pelton water-wheels. Each generator is connected directly through the switches on the switchboard and fuses to the primary of the step-up transformers, which are connected to transform from 2-phase to 3-phase, and deliver current at 15,000 volts to the transmission line. Four step-up transformers, each of 150 kilowatts, are connected on the Scott system in two pairs of two transformers each for the 2-phase to 3-phase transformation. The pole line is substantial and well constructed. The three wires for the main circuit are No. 4 B. & S. bare copper. The insulators are of the Locke pattern, triple petticoated and made to carry a current of very high potential without cracking or puncturing. They are secured to the cross-arms by steel pins, thus providing a solid support for the wires. Each end of the transmission line is protected by Wurts non-arcing metal lightning arresters. At the sub-station there are three pairs of 75 kilowatt step-down transformers, which receive 3-phase current and deliver 2-phase current at 2,000 volts to the bus-bars of the distributing switchboard. The circuits are supplied with standard transformers for reducing the current from 2,000 volts to 100 or 200 volts as may be required.

In the sub-station are two 50 horse-power induction motors, direct-coupled to 60 light direct-current series machines for supplying arc lights. The motors are supplied by two 75 kilowatt transformers, which deliver 2-phase current at 2,000 volts.

ELECTRO-METALLURGICAL PLANT AT MERCUR, UTAH.

The next feature to be shown will be the application of electricity for operating the machinery of the largest cyanide mill in the world, the Golden Gate, at Mercur, Utah. The current is generated at Telluride, by water-power, and transmitted a distance of 35 miles at a potential of 40,000 volts. The transmission line, which runs through a very

rough and unsettled mountainous country, is of very substantial construction, and the insulators were especially designed for safely carrying current at a very high potential. These are the triple-petticoated glass insulators known as the "Provo," and are made by the Hemingray Glass Company, of Covington, Ky. They were tested under a potential of 50,000 volts, salt water test, before being shipped from the factory, and not one has ever failed to do its duty. Some have been shot to pieces, but no harm other than the burning off of a few cross-arms has ever resulted, and they give entire satisfaction.

Omitting the description of the power plant at Telluride, I will start with the electrical apparatus in and about the mill. All of the electrical apparatus is of Westinghouse manufacture, and the success that has attended the use of this machinery is noteworthy. The loss of electrical energy in transmission is extremely low, being about 5 per cent.

The current is converted in the transformer house from 40,000 volts, 3-phase, to 220 volts, 2-phase. Current is delivered at the mine at $60.00 per horse-power per year, with a minimum consumption of 300 horse-power stipulated. In the high-tension room are the Wurts lightning arresters, the choke coils and the high-tension lines. Special care is taken in insulating.

The ore is hoisted by a 150 horse-power motor, Type C, direct-connected to hoist. The crushers weigh 20 tons each, and have a combined capacity of 1,500 tons daily. They are operated by two 50 horse-power Westinghouse motors, Type C. Another of these 50 horse-power motors operates the roaster and ore converter. A 20 horse-power Westinghouse Type C motor at the same mill drives a centrifugal pump. The plant is operated entirely by 2-phase induction motors, aggregating 700 horse-power, all of Westinghouse Type C.

While illustrating the applications of electricity to mining, I will call attention to the General Electric Company's mining drills and mining locomotives. One of these, of which I show a view, weighs about 6½ tons, and has a drawbar pull of 1,500 pounds on the level at 6 miles per hour.

I show you also the electric hoist in the Free Silver Mine, at Aspen, Col. This is said to be the largest electrical hoist in the world. The electrical equipment consists of one General Electric Company's 100 kilowatt multipolar motor, with a speed of 550 revolutions per minute, and a smaller motor of similar type of 60 kilowatts and a speed of 475 revolutions per minute. The smaller motor can be thrown in gear with the main hoist-motor when the load is unusually heavy.

MECHANICSVILLE-SCHENECTADY POWER PLANT.

The Mechanicsville-Schenectady Power-Transmission Plant has been described with considerable detail in the leading electrical journals, and is, no doubt, by reason of its importance, quite familiar to all present. This plant is only 17 miles distant from the city of Schenectady, where are located the largest electrical works in the world, covering about 130 acres of ground. To this city the water-power of the Hudson River is transmitted electrically, and utilized by the General Electric Company in the manufacture of electrical machinery.

The site for the dam and the power-house, where the banks and bottom of the river are of rock, seems to have been designed by nature to meet the requirements of the most exacting engineer. The water-power is sufficient to produce from 8,000 to 10,000 horse-power for the greater part of the year.

Bluff Island divides the Hudson into two channels. The power-house starts from the west bank and extends out into the river about 215 feet, and is connected with Bluff Island by a concrete dam. On the eastern side of the island is the main dam, which is built entirely of concrete. The up-stream face of the dam is vertical, the down-stream face is curved, and the horizontal apron, 14 feet wide, throws the water off horizontally, and prevents scouring of the toe of the dam.

The abutments are anchored to the rock sides of the river bank and the island. The spillway between the abutments is 800 feet long. In the western abutment are 12 arched

waste-gates, each 4 feet wide and 6 feet high. A floating wooden boom anchored to a line of stone cribs above the dam prevents floating rubbish or ice from choking the waste-gates.

The foundations of the power-house are carried down to bed rock, and the house is carried on steel box web girders resting upon steel I-beam columns. These columns are imbedded in concrete walls carrying arches spanning the tail races and forming the floor of the generator room and the wheel flumes. Division walls form a separate and distinct tail race 22 feet wide for each set of turbines, from which the water can be shut off at will. A thick head-wall divides the house into two parts. The up-stream part contains wheel chambers for seven 1,000 horse-power wheels and two exciter wheels. The down-stream part contains the water-wheel governors and the generators and switchboard. The power-house is 257 feet long; the wheel room is 32 feet wide, and the dynamo room is 34 feet wide. A 20-ton crane runs the length of the dynamo room.

Each main turbine consists of two pairs of 42-inch horizontal Victor turbines, built by the Stillwell-Bierce & Smith-Vaile Company, of Dayton, O. Each set of four wheels is rated at 1,000 horse-power under an 18-foot head. The turbines for each exciter consist of three 18-inch Victor cylinder gate wheels (arranged as a pair with a central discharge and one single wheel), developing a total of 300 horse-power at 259 revolutions per minute. The speed of each set of main wheels is regulated by a Geissler electro-mechanical governor placed on a platform over the turbine shaft and between the head-wall and the dynamo. These governors can move the gates through their full travel in six seconds. Snow governors control the exciter wheel gates.

The generators are 3-phase, forty pole, 750 kilowatt General Electric machines, having internal revolving fields and stationary armatures, wound to deliver 36 ampères of current at a periodicity of thirty-eight cycles and at a potential of 12,000 volts to the transmission lines when running at 114 revolutions per minute. The armature frame is 15 feet

4 inches in diameter and 36 inches wide. The field ring revolves on a shaft 15 inches in diameter, rigidly coupled to the turbine shaft. On each side of the stairway leading to the switchboard gallery are located the exciters. The switchboard consists of nine panels. Five are used for the generators, two for the feeders, one is the total output panel, and the ninth is fitted for the control of the exciters. The details of the switchboard equipment are interesting, but it will take up too much time to enumerate them. In a small house near the first pole are placed double-pole 2,000 volt, short-gap lightning arresters, connected six in series to give the necessary number of spark gaps, which are each $\frac{1}{32}$ inch long. The line consists of three No. 000 B. & S. bare copper wires. The circuits are carried on poles 30 to 60 feet long, 8 inches in diameter at the top. Triple-petticoated insulators are used.

All of the machinery of the General Electric Company in their Schenectady plant is driven by electric motors, so that the change from steam-power on the ground to water-power, developed and transmitted 17 miles, will not necessitate many changes. The steam plant will be retained as a reserve in case the water-power should fail.

The General Electric Company furnished all of the electrical equipment. The Stillwell-Bierce & Smith-Vaile Company, of Dayton, O., were entrusted with the entire development, taking the river in its natural condition and building the plant, turning it over to the operating company in thorough running order, having used throughout hydraulic equipments of their own manufacture.

COUPLING WATER-WHEELS AND GENERATORS—MISCELLANEOUS APPLICATIONS OF ELECTRICITY FOR POWER PURPOSES.

I invite your attention to some views illustrating the methods employed for coupling water-wheels and generators, and also the very wide range in the application of electricity for power purposes.

Of interest are the two 450 kilowatt 3-phase General Electric generators of the Portland General Electric Company, at Portland, Ore. They are driven by vertical turbines

made by the Stillwell-Bierce & Smith-Vaile Company. The weight of the vertical shaft, with the armature, is about 33,500 pounds, and to carry this a system of extra bearings is introduced, one of the ring-thrust type, and the other a hydraulic oil bearing, both supplementing the ring bearings on the armature shaft. They are enclosed in cases filled with oil, delivered by hydraulic pressure, and are surrounded by water jackets. The generator shaft is 29 feet long and $8\frac{3}{8}$ inches in diameter. Direct current exciters are used for the 3-phase generators. The direct current for the railway service is obtained by means of rotary converters. Each converter delivers 500 horse-power to the bus-bars of the continuous current switchboard.

At the St. Anthony Falls water-power plant, several 700 kilowatt 3-phase generators furnish the current for operating nearly 240 miles of street railway in the twin cities of Minneapolis and St. Paul. The apparatus seen belted to generator No. 8 is a Lombard water-wheel governor. The Lombard governors are used with the other turbines which drive the generators.

The power plant of the Pioneer Electric Power Company, of Ogden, Utah, is also worth noticing. The water-wheels are of the impulse type, and are directly connected to the generators. Under an effective head of 416 feet the wheels have a capacity of 1,200 horse-power each at 300 revolutions per minute.

A $\frac{1}{4}$-inch steel pipe 24 inches in diameter conveys water under a head of 1,411 feet (having a pressure of 609 pounds to the square inch) to the 60-inch Pelton water-wheels, which drive the generators of a light and power plant. Three 3-phase 350 kilowatt G. E. generators are driven by the large Peltons, and three small Peltons operate the exciters. The current is generated at 700 volts, and nine 125 kilowatt transformers raise the voltage to 11,500 volts, at which voltage it is delivered to the transmission line.

At the Electric Light Company, Columbus, O., Leffel Cascade 18-inch water-wheels of the impulse type are direct-connected to the generators. The six generators of the Boise Electric Light Plant are driven by a 26-inch double-

discharge Leffel turbine, with six clutch pulleys. Any one generator, or combination of them, can be run at pleasure. The generators of the Skowhegan Electric Company, Skowhegan, Me., are driven by two 56-inch Leffel vertical turbines, which operate under 13 feet of head. The power station of the Electric Light and Power Company, at Raritan, N. J., operated under a head of 13½ feet, is driven by 40-inch wheels of the same make.

A point which I wish to illustrate is that the use of vertical turbines and heavy gearing is necessary when the fall is not great and waste of water is not permissible. Thus, I show you an installation in which the turbines are belted to pulleys on the main-line shaft extending the whole length of the wheel-room and continuing through the partition walls into and along one side of the generator-room of the power-house of the Ponemah Mills, Taftville, Conn. This power-house is located at Baltic, 4½ miles distant from Taftville. The pulleys are put into, or out of, action by clutches mounted with pulleys on quills, so that any one, or all, of the wheels can be applied to driving the shafts.

The belted generators are G. E. 250 kilowatt 3-phase generators, which deliver current to the line at 2,500 volts. At Taftville the 3-phase circuits are led into the basement of the mill, where they drive two 3-phase synchronous self-starting motors. These motors furnish power for driving the 1,700 looms, the lighting plant and three 80 horse-power G. E. railway generators. This was the first important application of electrical power transmission to textile manufacture.

In the Carolinas and Georgia are many valuable water-powers, and capital has been steadily invested in these powers during the last five or six years, and several notable electrical developments have been made.

I have some interesting views which show only a very small portion of the largest and greatest water-power development on earth. You know, of course, that I refer to the enduring monument to engineering skill and genius built at Niagara Falls by the noted engineer, Dr. Coleman Sellers. No hydraulic and electric plant was ever built

where such tremendous engineering difficulties were encountered at every stage of its progress, and yet, thanks to the genius and perseverance of the engineers employed in the different branches of the development, every difficulty was promptly met and perfectly solved. This plant has been very ably written up and profusely illustrated in the edition of Cassiers Magazine for July, 1895, and was made the subject of two numbers of *The Electrical World* in January, 1899.

The speaker here showed a number of views illustrating the exterior and interior of the Niagara power plant.

The Pelzer Manufacturing Company, at Pelzer, S. C., one of the largest manufacturers of cotton goods in the South, has a well-equipped electric-power plant. The transmission plant consists of three pairs of 60-inch turbines, made by the Stillwell-Bierce & Smith-Vaile Company, direct-connected to three 750 kilowatt 3-phase G. E. generators, wound for 3,300 volts. The power is carried three miles to the mills. The motors consist of one 400 horse-power synchronous motor, wound for high potential, fifteen 110 horse power, four 75 horse-power, two 50 horse-power, one 20 horse-power, and four 5 horse-power, a total of 2,530 horse-power. Most of these motors are of the inverted type, and are suspended from the ceiling, and receive current at low potential from step-down transformers, located in the sub-station at the mills. The mills are lighted by 1,200 incandescent lamps, from the same power. The electrical equipment throughout the entire plant was furnished by the General Electric Company.

The electric plant of the Columbia Mills Company, of Columbia, S. C., also deserves notice. Two pairs of 48-inch horizontal turbines, made by the Stillwell-Bierce & Smith-Vaile Company, operated under 26 feet head of water, develop 2,000 horse-power. One 24-inch wheel under the same head develops 190 horse-power, making a total of 2,190 horse-power. This power drives two 500 kilowatt 3-phase generators, direct-connected to the turbines, running at a speed of 108 revolutions per minute. The power is transmitted a distance of $\frac{1}{8}$ mile to the mills, and there drives

1,775 horse-power of inverted motors, and these motors operate all of the machinery of the cotton mills.

These two plants illustrate better than words the advantages derived from the electrical development of water-powers, especially when the powers are utilized for manufacturing raw materials raised at the very doors of the mills. In the cases of these mills in particular, a large saving is made in the cost of power, and the use of individual ceiling motors dispenses with many feet of power-wasting shafting, and also saves a large amount of valuable floor space. The absence of many yards of belting gives better light to the employees in the building, and lessens their chances of being accidentally injured. Another point to be scored is the cheapness of living and the low cost of labor in the locality of these mills.

That this locality is a splendid field for the investor is shown in the interest taken by the Government in having all the water-powers in this section accurately measured. A very complete report has been published on "The Progress of Stream Measurements" by the U. S. Geological Survey. This publication very materially strengthens the views I advanced a few years ago: that this section offers splendid opportunities for a water-power development company. Such a company could buy the best powers and develop them at leisure. The cost of such developments would be exceedingly reasonable, since timber for buildings and pole lines and stone for dams are to be found wherever there are powers. There are many other features worthy of consideration, such as the building of factories for manufacturing many articles that are now brought to this section from a distance. Land about the factories would also be available for town sites, so that the original outlay would be gotten back in a few years.

There is little question but that powers not immediately developed would increase in value more rapidly than interest would accrue if the capital were invested at the present low rates of interest that are being paid on large sums of money.

A few statistics relative to water-power electric plants

may be of general interest, and, since they were obtained after the expenditure of considerable time and labor, I will try and present them in such shape as not to weary you.

In the first place, the method employed for securing accurate and reliable data was by personal correspondence with the electricians in charge of the plants, a list of the plants operated by water-power having been furnished me by the different manufacturers whose machinery was used in the plants.

There are nearly 500 water-power electric plants in the United States, representing an investment of over $60,000,000. The total horse-power represented by water-wheels is over 200,000. The power is furnished for lighting 28,000 arc lights, 845,000 incandescent lights and for operating about 60,000 horse-power of motors. There are over 610 miles of electric street railway operated by water-power electrically transmitted.

The geographical location of the plants shows that the water-powers have been electrically developed in proportion to the powers available. New England has no coal fields, but it seems that Providence has supplied this portion of the country with numerous large water-powers. Of the 312 plants from which I have received reliable data, 115 are located in the States of Maine, New Hampshire, Vermont, Massachusetts and New York. Michigan has twenty-six, California, twenty-five, and Colorado, eleven. The other plants are distributed among the other States.

It seems to be fairly well established that it pays to develop water-powers from 50 horse-power and upward, and that additional steam-power is necessary when the water-power is not sufficient to do all the work, and is not reliable at all seasons of the year. It is a well-settled fact that at the present time power can be profitably transmitted up to 80 miles, and utilized for any purpose for which steam-power has been applied. In mining localities it has made possible the profitable reduction of low-grade ores that could never have been mined had steam been the only power available, owing to the enormous cost of coal and the difficulty of transporting it from the nearest

point on railroads to the mines. In short, we find that our inventors have produced water-wheels, dynamos, motors and transformers of the highest efficiency, that governors regulate the water-wheels with the greatest precision, that insulators are made to safely carry currents of enormously high potentials, and that perfect protection is afforded the electrical apparatus from electrical disturbances caused by lightning.

Not until all electric light and power stations are equipped with total-output wattmeters, and accurate books are kept, showing the exact amount of fuel used and all of the expenses of operating the plants, will satisfactory data be available for comparing the cost of producing current by the two methods—water and steam. When sufficient progress has been made in adopting uniform methods of keeping station accounts, and accurate and reliable data can be secured, it is my purpose to obtain and publish comparative statements showing the cost of producing current by the two methods.

[The subject of the paper was profusely illustrated with the aid of stereopticon views.]

Mining and Metallurgical Section.

Special Meeting, January 25, 1899.

MALLEABLE CAST IRON—Its HISTORY IN THE UNITED STATES.

George C. Davis.

(*Concluded from p. 144.*)

Moulding sand was obtained from a place between Newark and Elizabeth. For cores, sand from Rockway, Long Island, was used, the binding material being wheat or rye flour. The patterns were usually made from white metal, though iron, brass or wooden patterns were sometimes used. Fewer pieces were moulded on the gate than is now

the practice, as it was thought impossible to run them. For one-inch buckles, from four to eight were placed on one gate, though several gates were moulded in each flask. The flasks were made of sheet iron, circular in shape, and were fastened together with a button and eyelet hole. The castings were cleaned in a tumbler, which was made from a keg strengthened with iron hoops. A door was cut in the side, and holes bored to let out the sand. Iron journals were bolted on the ends. The journal boxes were of wood, and power was furnished by a belt over the center of the keg.

The first annealing furnace was shaped like a beehive and the pots were inserted from the top, which could be removed by a crane. Mill scale was packed around the pots and whole kept at an annealing heat for a week. This type was succeeded by a rectangular furnace, which was run continuously. The floor was laid on an incline and the charging done from the higher end. The whole charge was moved along and pots were thus pushed out at the lower end, hence the name of "Shoving Furnace." This furnace was closed by large bungs, luted at the joints, and held forty-eight pots, which were about 12 x 10 x 10 inches. They had a solid bottom, and after packing were covered with an overlapping tile, inverted, and the joints luted. The fire-boxes were on the side with inlet ports near the top of the furnace, thence the flame went to the upper end, and then down to the flues that led underneath the furnace to a stack near the lower end. Pine wood, charcoal or soft coal was used for fuel. The castings were cleaned in a tumbler with leather and stars. A considerable variety of castings were made, comprising, as a catalogue—a small card,* size 3 x 4

***S. BOYDEN,**

MANUFACTURER OF MALLEABLE IRON CASTINGS,

Bridge Street, Newark, N. J.

Catalogue of Articles.

For Coachmakers.—Coach wrenches; Pole hooks, Crabs and Stops; Tug hooks and Racks; Shaft Sockets & Hold-backs; Swivel-tree Hooks, Tongues, Ferrules and Loops; Coach Body, Door and Footboard Handles; Gig Body, Wing & Dash Handles; Hub Boxes, Bands, Caps and Axle Nuts; Spring, Shaft and other Steps; Perch and Body Wear Irons; Perch, Body

inches, and printed on one side—states, over 1,000 different articles. Among the articles enumerated are "Cavasons for the Spanish market." Judging from this, Boyden was as fully alive to the advantages of the foreign trade as are some of our modern imperialists. It may be necessary to explain that a cavason was a ring with a staple cast on it that could be put on the nose of a horse in order to wrench it and facilitate breaking in. The demand for castings was mainly local, and at first they met the opposition encountered by any new article. The blacksmiths objected to the variable character of the metal and feared it would do away with much of their trade. The prices obtained at first were about 25 cents per pound, but they gradually fell to 8 cents by 1854, and afterwards rose somewhat after the Civil War.

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and other Check Loops; Te, Baggage and other Bolts; Square, Cap and Thumb Nuts, Brace Buckles, Rollers and Shackles; Bow Irons, Joints & Props; Lamp Props, Seat Rails, Te and Connecting Plates; Back Strap Hooks and Plates; Double and Single Footmen Holders, Coach Hinges, Dovetails, Seat Irons, Check Territs, Sand Bands, Linch Pins, Tire Nails, Washers, Boot Loops, Hooks, etc.

For Platers.—Bits, Stirrups, Turrets, Hooks, Hame Turrets, Hame Clips, Links and Rings, a general assortment of Buckles and Tongues to suit; Trace Bolts, Plates and Loops; Crooper, Pad, Saddle and other Loops; Swivels, Dees, Rings and Rivets assorted, Band Screws, Pad Screws, and Nut —also Steps, Buckles, Bits, Handles, Shaft Caps, and Cavasons for the Spanish Market.

For Gunsmiths.—Butt Plates, Guards, Side Plates, Cups, Sights, Loops, Slides, Breech Pins, Triggers, Trigger Plates, Set Trickers, Rifle Boxes, Dirks, Screws and Limbs of Locks.

For Cutlers and Surgical Instrument Makers. Knives, Forks, Spoons, Snuffers, Shears, Scissors, Pincers, Pliers, Tooth Keys, Saw Backs, Spring Boxes, Handles, Screws, etc.

For Locksmiths.—Boxes, Bolts, Keys, Spindles, Staples, Screws and other Limbs; Knobs, Handles, Latches, etc.

For Machinists.—Wrenches, Screw Tools, Lathe Work, Clamps, Parts of Spinning, Weaving and other Machinery.

For Blacksmiths.—Ornaments for Iron Fence, Scrapers, Sash, Blind and Shutter Fastening; Carpenters' Hammers, Squares and Compasses, Garden Rakes, Forks, Hoes and Trowels, Iron and Coffee Stands, Shovels and Tongs, Stove Latches, Catches & Door Handles, Kettle Ears, Trowel Shanks, Limbs of Coffee Mills, and many other things not enumerated. The Collection consists of more than ONE THOUSAND plain and ornamented patterns of Iron articles now in use.

In the early thirties, Otis Boyden, a brother of Seth, had started the Crockett Foundry in Newark. This works was burned down in 1835, in which year the Boston M. I. C. & S. Co. bought out what was left of the Crockett Foundry's equipment and also Seth Boyden's establishment, where they continued in business until 1837, when they failed. Thus Seth Boyden's connection with the malleable iron industry ended in 1835, after continuing nine years, though, as we shall see later, several of his brothers started other foundries. The Boston Company were succeeded by a stock company, which from time to time underwent various changes in membership, until at the present day the place is operated under the firm name of Morris & Barlow. Part of the original building still stands, serving as the wall of the present foundry, though it has been raised several feet.

The extension of the malleable iron industry was very rapid, and several foundries were started in various places at about the same time. Many of the concerns were short-lived, as they suffered from the financial troubles of 1837 and the difficulties encountered by any new process. It is impossible in the time at my disposal to do more than briefly refer to some of the others. There were two concerns in Elizabethport, of which I have been unable to learn very much, except that they were probably started previous to 1840. David Meeker began making malleable iron in Hedenburg's Works, in Newark, in the year 1841, but removed two years later to his present location, where the business is now conducted by S. J. Meeker. The New Jersey Malleable Iron Works was started in 1848 on the spot where the Market Street Station of the Pennsylvania Railroad now stands. At one time there were said to be eight malleable iron foundries in Newark. In 1833 Calvin Adams started a malleable iron foundry at Oak Hill, Greene County, N. Y. A branch of this concern was established at Westmoreland, N. Y., in 1850, under the title, The Oak Hill Branch Malleable Iron Company. The original works at Oak Hill was continued for a few years, when it was moved or sold out to parties who formed a corporation at Coxsackie, N. Y., where they continued in business for some years. The West-

moreland foundry continued for some time as a branch of the Oak Hill Works, but after severing its connection with the parent concern took the name of Westmoreland Malleable Iron Works, under which it is now operated. These works have largely been devoted to such light castings as saddlery and harness hardware, gun and pistol work and steel trap castings. Calvin Adams is supposed to have removed to Pittsburgh, Pa., where he may have started other foundries.

The malleable iron industry in this city was first started in 1833, at Susquehanna and Germantown Avenues, by Stellwagon & Bryant. This works was a small one, employing some ten or twelve moulders—it was probably an offshoot of the Boyden Works in Newark, as at least two of the moulders came from that place. The works' practice, so far as can be learned, closely followed that already described. Carriage hardware, coffee-mills and small articles were the chief products. According to the custom of the times, great secrecy was observed, and for what few details of the business now attainable I am indebted to Mr. John Dessalet, of this city, who was a moulder in these works. Mr. Dessalet, in his ninetieth year, is hale and hearty, and is undoubtedly the only man now living who was connected with them. He states that Mr. Bryant was the practical man of the concern, and carried on many experiments, but none of the men, except one laborer, selected for his ignorance, were allowed in the annealing room. One attempt to add something to the molten iron resulted in an explosion which cost one man his eyesight. The iron was melted in a small air furnace, which ran under natural draft, and could not have been very economical of fuel, as it is stated that flame often showed at the top of the stack, which was 80 feet in height. New Castle coal was imported in considerable quantities. The fire-brick, Stourbridge, also came from England. These works continued some five or six years, when the business was abandoned, though for what reason it is not known.

In Massachusetts the malleable iron business was first established in East Boston, about 1835, by a company incor-

porated with a capital of $100,000, and under the management of Alex. Boyden, a brother of Seth. A younger brother, Frank, was also employed there. This concern only ran about two years, as there was not much demand at that time for machinery castings of malleable iron. The company made stock goods, such as hammers, axes, chisels, etc., very little light cored work being attempted. They evidently followed along the lines of the earlier English works, as large quantities of castings were made under the impression that they were steel. These could not be sold, and, as no dividends were forthcoming, the stock was bought up by a few persons, who crowded out the Boydens. So far as can be learned, the practice in these works differed in no essential from that already described. "Flat Bar" Salisbury pig was used, and the melting was done in two air furnaces, capacity 1,000 and 1,600 pounds, respectively, the latter being considered a large furnace at the time. Flat Bar was the common name for Salisbury iron, but from which of the furnaces it came, or whether it was common to all of them, I have been unable to learn. A cupola was erected, but for some reason did not succeed. It is said that the packing was oxidized with sea water.

In 1837 Alex. Boyden was employed by Frederick Fuller, of Easton, Mass., who at that time was operating the Easton Iron Foundry, established in 1752, to start a malleable iron foundry in Easton. The land and foundry buildings were leased to Boyden for $350 per year. The lease begins, according to the old legal form: "This indenture, made the first day of March, 1837, by and between Frederick Fuller, of Easton, in the county of Bristol, gentleman, on the one part, and Alex. Boyden, of Easton, in the county of Bristol, iron founder, on the other part, witnesseth, etc." Evidently in those days the distinction between an iron founder and a gentleman was sharply drawn. The foundry was continued under Boyden's management about a year, when his interest was bought out by Lincoln Drake, who was the executor of the Leach estate, owners of the Easton Foundry, who had been Fuller's financial backer. Boyden agreed not to establish or help establish any other malleable iron foun-

dry in New England. In 1838 Daniel Belcher took charge, buying out the business ten years later, and continuing it until his death, which occurred in 1890.

I am indebted to George C. Belcher, the present proprietor of these works, for many of the interesting details of the early practice, and feel that I cannot do better than give the account in his own words. He says: "At these works about one-quarter flat bar Salisbury and three-quarters Sterling iron was used, which was valued in the inventory, taken 1840, at $50 per ton. The moulders made their own cores, dumped and trimmed their own castings and helped the melter when skimming the slag from the air furnace, for all of which they received $1.25 per day. The fuel used in the air furnace was Pictou coal, costing $14 per chaldron or thirty-six bushels and pine limbs. The charge was 800 pounds, sometimes 1,000 pounds, and the writer well remembers when the melter, without consulting the boss, had the temerity to put in 1,500 pounds. With what anxiety all watched the furnace for something to happen, expecting the bridge to give way and let the iron back onto the grates or that the whole charge would puddle and refuse to run when tapped. The bottom of the air furnace was made up of quartz mixed with a little clay, and stood about sixteen heats. The quartz was obtained in the neighborhood, and was first calcined in the air furnace and then pounded up. Stourbridge fire-brick were in common use at this time in the construction of the furnaces. The annealing furnaces were also run with Pictou coal and pine wood, the firemen firing up every fifteen minutes. The annealing pots were pushed in on rolls at one end of the furnace and pushed out when done at the other end by the introduction of fresh pots." Very soon after he took charge Mr. Belcher built a hard coal annealing furnace, which, while building, was ridiculed by all old hands, including the melter, who was from Newark, but, proving successful, was afterwards claimed by the melter as his own invention. The castings made at first were carriage, harness and stove trimmings, fliers for cotton speeders and fly frames, pump castings, mule fingers, loom forks, keys, axle nuts and shanks for gar-

den trowels. Pipe fittings were manufactured here as early as 1849, and possibly earlier. They were shipped to Walworth & Nason, of New York City, to have the threads cut. The price obtained for axle nuts in 1840 was 12½ cents per pound; stove trimmings, 15 cents per pound. Average price of castings, including cored work, 16⅔ cents per pound, or one shilling. Large speeder fliers, however, brought 50 cents per pound. In looking over the old patterns some years ago I found that many of them were finished and gated in a superior manner. Match plates, similar to those now used in machine moulding, were employed with good success and moulds were made rapidly. The flasks were made of cherry wood, and the workmanship on them was of the best. I am indebted to Horace Spaulding, of Easton, for much of my information. Mr. Spaulding, who is now 83 years of age, was a moulder in the East Boston Foundry, and is the only person now living who was concerned in the malleable iron works when first started. He relates that in the early days of the business Alex. Boyden used to have a little pump or syringe with which he used to squirt something into the air furnace stack, and also used to drop some kind of metal, probably zinc, into the molten iron, creating a smoke, all of which was to make a mystery of the process in the minds of the workmen.

One of the first malleable iron foundries in the central West was established in Cincinnati, O., previous to 1850, and possibly as early as 1845, by Miles Greenwood and Thomas R. Wood, under the firm name of M. Greenwood & Co. So far as can be learned, the works' practice was similar to that already described. Missouri surface ore pig was considered essential, and commanded an extra price on that account. The iron was melted in a cupola and later an air furnace was erected.

One salient feature of the malleable iron industry is the great amount of experimental work done in attempting to improve the process. From the time Seth Boyden began his elaborate series of experiments down to the present day, neither time nor money has been spared in putting into operation new methods. Most of these efforts have

been directed towards improving the annealing. Of course we always have had and probably always will have with us the man with the mysterious substance or "flux" which was to be added to the cupola charge or molten iron, and which was to produce malleable iron direct without any subsequent annealing. These metallurgical operations were usually accompanied by some financial operations on the foundryman's bank account, and this being accomplished, the man with the flux usually departed just before the heat was to be poured, to be seen no more.

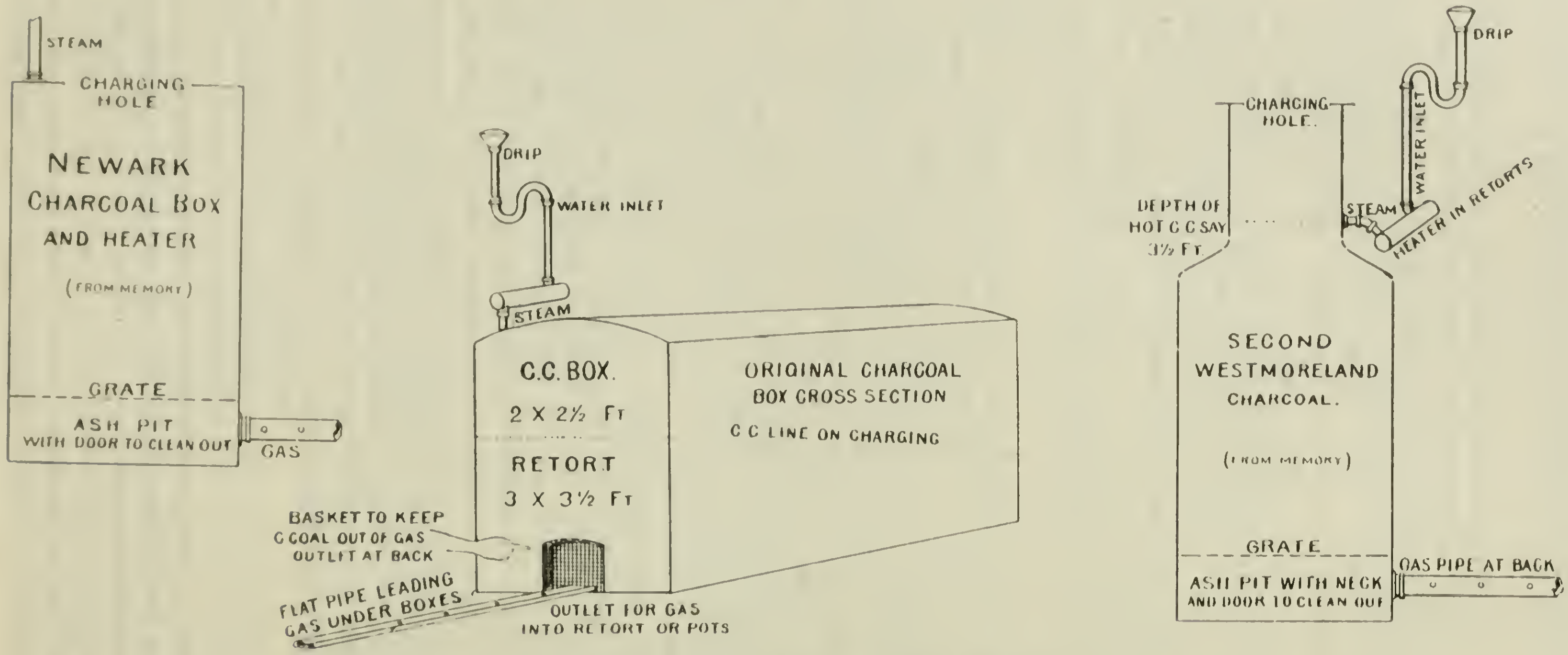
One attempt to introduce a new method of annealing, which was known as the Andrews process, was tried at a number of plants about 1875. The process consisted in passing water gas, which is composed of carbon dioxide, carbon monoxide and hydrogen, over the castings heated to redness. The water gas was generated by passing steam through red-hot charcoal in a retort contained in the large retort in which the annealing boxes were placed. Both the retort for generating the gas and that contained in the castings were heated from the same source. The plant consisted practically of a small water gas plant inside of a retort or annealing oven, suitable connections, of course, being provided for passing the gas over the castings and providing for its escape. The process could be made to work fairly well, but the mechanical difficulties of keeping the gas pipes, which were subjected to high temperatures, in good order were very great. Under the conditions which the Andrews process was installed, the proportion of carbon dioxide was probably too large, considerable steam was passing through the charcoal, and these two chemical reasons, with the mechanical difficulties mentioned above, caused the abandonment of the process. The reaction on which the decarbonizing process probably depended was the oxidizing action of carbon dioxide. This gas, by itself, is so active that both iron and graphite will be attacked; in other words, a scaly casting will result. Provided the carbon dioxide be diluted sufficiently, it still is able to oxidize the carbon, but will not attack the iron. At the time the process was introduced the idea was held that the hy-

drogen combined with the carbon to form some volatile hydrocarbon. These two elements do not unite directly, except at the temperature of the electric arc, when acetylene is formed.—"Richter's Organic Chem.," p. 153. In this case, as we are dealing with the ordinary temperature of the annealing retort, less than 1,000° C., it is highly improbable that this reaction could have taken place. Experiments with the Andrews process were carried out at the works of the Westmoreland Malleable Iron Company. Mr. F. M. Metcalf, treasurer of this company, has communicated to the writer his experience with this process. His account of the experiments, which extended over several years, is quite interesting, and I quote his letter, merely omitting some of the names.

WESTMORELAND, ONEIDA CO., N. Y., January 26, 1899.

Mr. Geo. C. Davis.

DEAR SIR:—Replying to your inquiry of the 25th, will say the water in the Andrews process of annealing was dripped into a funnel and ran through a pipe with a trap or bend in the pipe down through the top of the retort into an oval casting called the heater, which was at the top of the retort, just above the box of red-hot charcoal, which served as a water gas generator. Both received their heat in the same way through the brick in the retort. This was supposed to be sufficient to reduce the water to steam, and to some extent to superheat it, though Andrews did not favor superheating much. Steam passed from the heater into the top of the front of the charcoal box, which was as full of charcoal as practicable, and supposed to be all red hot, the same as the annealing boxes and contents when under heat. The steam having no other outlet, and the charcoal box being steam- and gas-tight, it passed down through the hot charcoal and out at the bottom back end of the charcoal box into a pipe leading under and by latch connections into the annealing boxes. In passing through the hot charcoal, it was theoretically converted into hydrogen and carbon monoxide. Over the opening in the charcoal box, where the gas made its exit, was an iron basket to protect the outlet from getting full of charcoal. There was very little pressure, as there was nothing but a six- or eight-inch column of water in the trap to prevent the steam backing out, and I think we had no check valves. I think I suggested higher pressure and hotter steam to Andrews, but he did not favor the steam being very dry, as I think he had tried superheated steam. I have given you rough sketches to show as well as I can with the short time at my disposal. The original charcoal box was rectangular, and say about five feet long. It was charged with charcoal through a luted door at the end and filled as full as possible, always fullest at the back, and after running a day or two was, of course, exhausted to a considerable extent. This reduced the depth of hot charcoal through which the steam was obliged to pass to so shallow a mass that it was thought that at that point the steam was not effectually converted, and



ANDREWS PROCESS OF ANNEALING CAST IRON.

Experiments made at the works of the Westmoreland Malleable Iron Company, Westmoreland, Oneida County, N. Y.

to that we attributed the scaling to which I referred in my last letter. As Andrews was about to build another such furnace in Newark, and intended to change the shape of the charcoal box to remove this difficulty, we discontinued using the process, and awaited the results of the change. One of the sketches is intended to represent the upright cylindrical box which was made for the Newark furnace, the idea being merely to keep it nearly full at all times, as was more easily done in an upright box, at least as high up as it got heat, and thus ensure a uniform and sufficient depth of charcoal to thoroughly convert the steam into gas of the right kind.

This effort failed, as you say, and it was thought by Andrews that the diameter of the charcoal box was too great, so that the charcoal did not get heated all through, thus allowing steam to pass that did not get converted. We then did not open up on it again, but about two years later, upon the introduction of brick packing into the charge of casting in a furnace that had been built in New Haven, we started up again and used this method for some months with fair but not entirely satisfactory results. To improve results we then made a new charcoal box of a bottle shape and heated it to as high a point from the bottom as was practicable, and hoped, by thus passing the steam through as great a depth of hot coal as possible, to be successful in getting rid of the carbon dioxide and unconverted steam that caused the scaling, which always appeared to a greater or less extent in some part of the charge, usually at the bottom, where the gas first entered. This failing, we introduced a condenser and passed the supposed converted gas through it to take out any unconverted steam before passing the gas into the annealing pots. This failed and then the whole oven failed and began to disintegrate to such an extent that we did not continue the effort. We have heard of gas annealing ovens that were claimed to be successful, though we could never place them exactly. If you know of any, we would be glad to hear of them, as we have always thought that there ought to be some successful way to improve the process by annealing with gas, but we have not "hankered" ourselves after any more experimenting in that line at such expense as we did the above.

As we understand it, the process was first used by ——— at ———, where we went to see it. We thought we saw it as it was, and became victim No. 2; ——— & ———, of Newark, were No. 3. I went to see their success on the third round of the furnace by Andrews' desire, but they had just completed what I was convinced was the third failure when I arrived, and I never learned whether Ballaid survived the great anger under which he was suffering on my arrival or not. Meanwhile, Andrews had just received a letter from the ——— people, saying that they were still using it right along with "charming results." Andrews, Minchen and myself went to ——— to see those charming results, and found they were worse than our worst. Shortly after that ——— discontinued using the process, and I think the next furnace was built in ——— shop in ———, for making steel from malleable iron by decarbonizing, and also by arresting the decarbonizing process at the steel point. The ——— & ——— Company were the fourth victims, and we followed on as the fifth, as above stated.

At this distance of time my sensitive feelings will not be hurt by any reference that you may wish to make to the process and our connection with it,

and we certainly have no objection to have you refer to the matter to such extent as you wish. We hope no one will think, however, that we have not learned to experiment more conservatively than we did then, though we are always open to improvements. I have answered you at much greater length than I intended, and hope, if you get tired reading the effusion, you will be compensated fairly by laughing at the victims, as I have learned to do.

Yours truly,

[Signed] F. M. METCALF, *Treas.*

Up to the breaking out of the Civil War there were few, if any, radical changes in the malleable iron production. With the growth of the country the business had gradually extended and foundry appliances had been enlarged and improved. The pig was obtained, as in the early days, from the Salisbury district, Orange County, and the Champlain district in New York State, and other furnaces scattered along the Atlantic seaboard from Katahdin in Maine to Stickney in Maryland. About this time there was experienced considerable trouble with the iron, owing to changes occurring in blast furnace practice. The hot blast was coming into use and the natural result was a higher silicon iron, unfitting it, in many cases, for malleable castings. As technical chemistry was then an unknown science, there was no reliable means of ascertaining in advance whether a lot of iron would answer or not. Some founders met with considerable losses owing to bad castings, which, though annealed soft, were still brittle. Naturally, they attributed all their troubles to the iron, a habit, by the way, that is not altogether unknown in the present day. Steps were taken to remedy the trouble, and in some cases men were sent to the furnaces disguised as workmen to find out whether hot blast was the sole cause of the difficulties or whether it was due to different ores. One manufacturer sent a man to visit the charcoal furnaces and obtain a sample of pig iron from each. This was sent back to the foundry, melted in a crucible and annealed. Such methods as these were expensive and required time before the result could be known. Even then there was no assurance that the next lot of iron would be suitable. Such experiences as these are, perhaps, worth recording, as they serve to illustrate the changed condition due to technical methods now

in use. At the present time, when a founder buys iron he orders it subject to certain chemical specifications, and he cares very little where it comes from or how it was made.

With the outbreak of the Rebellion, there arose an increased demand for iron for ordnance work, and the product and the output of many of the blast furnaces which had heretofore supplied the malleable iron foundries were absorbed by the U. S. Government. Fortunately, the Lake Superior region had been developed, and as pig iron from this district was found to be admirably suited for malleable work, its use rapidly extended. The first Lake Superior iron was brought into this locality about 1862. The source of supply of charcoal malleable is still from the lake region.

The malleable iron industry has undoubtedly been developed to a greater extent in the United States than in any other country. Mr. R. A. Hatfield, *Journal B. I. and S. I.*, vol. I, 1897, page 180, says, in his discussion of a paper by Mr. G. P. Royston, on malleable iron: "The author's paper was especially valuable, too, as calling attention to a line of work to which they in the United Kingdom had not paid sufficient attention; that was the production of malleable iron castings, for in America that industry was carried on on a very large scale. Its production had been so thoroughly specialized that he questioned whether they could touch either the price or quality which were being obtained in the United States. A large user in Sheffield had told him that he had to send for execution in America very considerable requirements, the price of castings being exceedingly low, the quality excellent, and time of delivery short, as compared with English makers." There are at present in this country about ninety malleable iron foundries, varying in capacity from one to eighty tons per day. Nearly all of them are located north of the Ohio and east of the Mississippi. They are quite evenly distributed over that region, though of the New England States, Maine and Vermont have none. There is in the Southern States only one malleable iron foundry, and in the entire West, from the Mississippi to the Pacific Slope, not one exists.

By far the heaviest tonnage goes into car castings and

farm implements. Since malleable castings have sold so low, they have, to a considerable extent, replaced gray iron castings for many purposes, especially in car building. Broadly speaking, the founders in the central West are mainly devoted to the heavier castings, while the Eastern foundries manufacture a very large variety of small articles, such as carriage and harness hardware, pipe fittings, bicycle fittings, ship hardware, parts of textile machinery, typewriters, gun locks, pistol frames and, to use a somewhat hackneyed phrase, "other articles too numerous to mention."

There are at present at least five coke blast furnaces that produce largely malleable pig. Two of these are in New York State, and one each in Pennsylvania, Illinois and Tennessee, so the source of supply is not centralized. The coke malleable differs from the charcoal in being a trifle higher in sulphur and considerably higher in manganese. The difference in sulphur is not great enough to be of any importance where the iron is melted in an air furnace, while the high manganese renders it desirable for mixing with charcoal irons, which are, as a rule, too low in this element. Coke malleable has now been in use for about fifteen years, and its consumption is undoubtedly increasing. It was thought at one time that some of the numerous steel casting processes would replace malleable iron. By steel I mean the product of the open hearth or modified Bessemer, and not any of the numerous semi-steels. In the heavier classes of work this has to some extent proven true, but, as a rule, the two processes are developing along different lines. The difficulties of preparing small moulds to withstand the high temperature of steel, and the more costly plant necessary for its production will probably prevent its use for small or intricate castings.

In closing, the writer wishes to acknowledge his indebtedness to Mr. O. S. Boyden, and the late W. G. Morris, of Newark, N. J.; Milton H. Robbins, of Lakeville, Conn.; George C. Belcher and Horace Spaulding, of Easton, Mass.; James L. Haven, of Cincinnati, O.; John Dessalet, of Philadelphia; F. M. Metcalf, of Westmoreland, N. Y., and Thos. Devlin, of Philadelphia, at whose suggestion this paper was undertaken.

Mechanical and Engineering Section.

Stated Meeting, held Thursday, March 9, 1899.

MECHANICAL APPLICATIONS OF COMPRESSED AIR.

(Abstract of remarks by Mr. W. L. SAUNDERS, M. Am. Soc. C. E., Member of the Institute, in opening the discussion.)

[*Concluded from p. 134.*]

At the same time the car is being charged with air, another nozzle is introduced to the heater connection, and live steam from the boilers is admitted, until the temperature registered is about 300° F.

The air storage reservoirs on these cars have a capacity of 51 cubic feet, sufficient to run the car eighteen to twenty miles continuously, or from fourteen to seventeen miles making the stops incident to ordinary street railway service. A larger capacity could readily be installed on the car, giving it ample power to run twenty miles with a reserve. The reservoirs consist of seamless steel flasks capable of standing a pressure of double that used without reaching the elastic limit of the metal and with no possibility of leakage. They are 9 inches in diameter and of varying lengths adapted to their location under the seats and the car floor. Between the flasks and the motor is placed a small tank containing 6 cubic feet of water, which is heated as before described. The tank is jacketed with non-conducting material preventing external radiation. This provides not only against loss of heat, but also against any perceptible rise in the surrounding atmosphere, so that no discomfort can arise from it.

Numerous trials have proved that the application of heat as employed in this system enables the cars to run nearly double the distance that cold air will carry them.

In operation, the compressed air, after passing through a reducing valve and being lowered to 150 pounds to the

square inch (the working pressure), circulates freely through the hot water, and a mixture of heated air and vaporized water passes to the motors, working expansively, the terminal pressure being so low as to cause no sound in exhausting the air.

The motor mechanism consists of two simple link-motion, reciprocating engines having cylinders 7 inches in diameter and 14-inch stroke, with valves cutting off at from 1-10 to 1-6, and applying the power by connecting and parallel rods

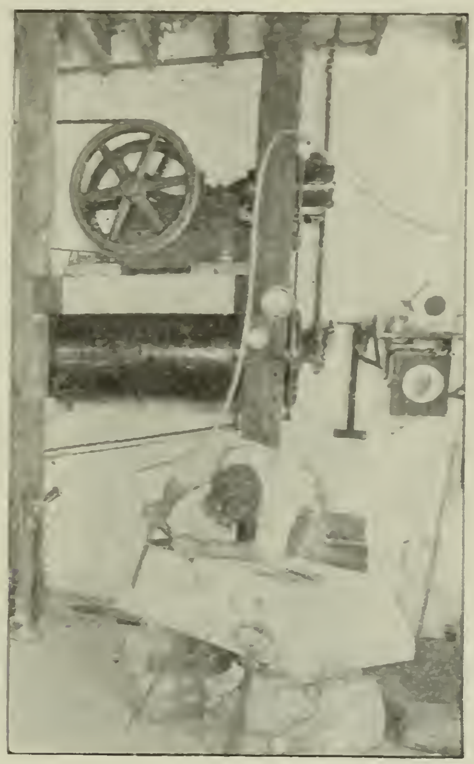


FIG. 26.--Lettering with the pneumatic tool.

direct to the crank pins of the drive wheels, which are four in number, 26 inches in diameter, running on a wheel base of 7½ feet. Upon this four-wheeled truck rests the entire weight of the car and mechanism, evenly distributed upon elliptic springs, enabling the car to pass much more smoothly over bad track and crossings than an electric car (on which the motors are a dead weight upon the axles), besides being a great saving in wear on the rails at the joints, and on the rolling stock.

The mechanical features of the motors are substantially

identical with those of a steam locomotive, minus fire-box and boiler, which, in point of perfection in mechanism as a moving power, is too well known to need any comments.

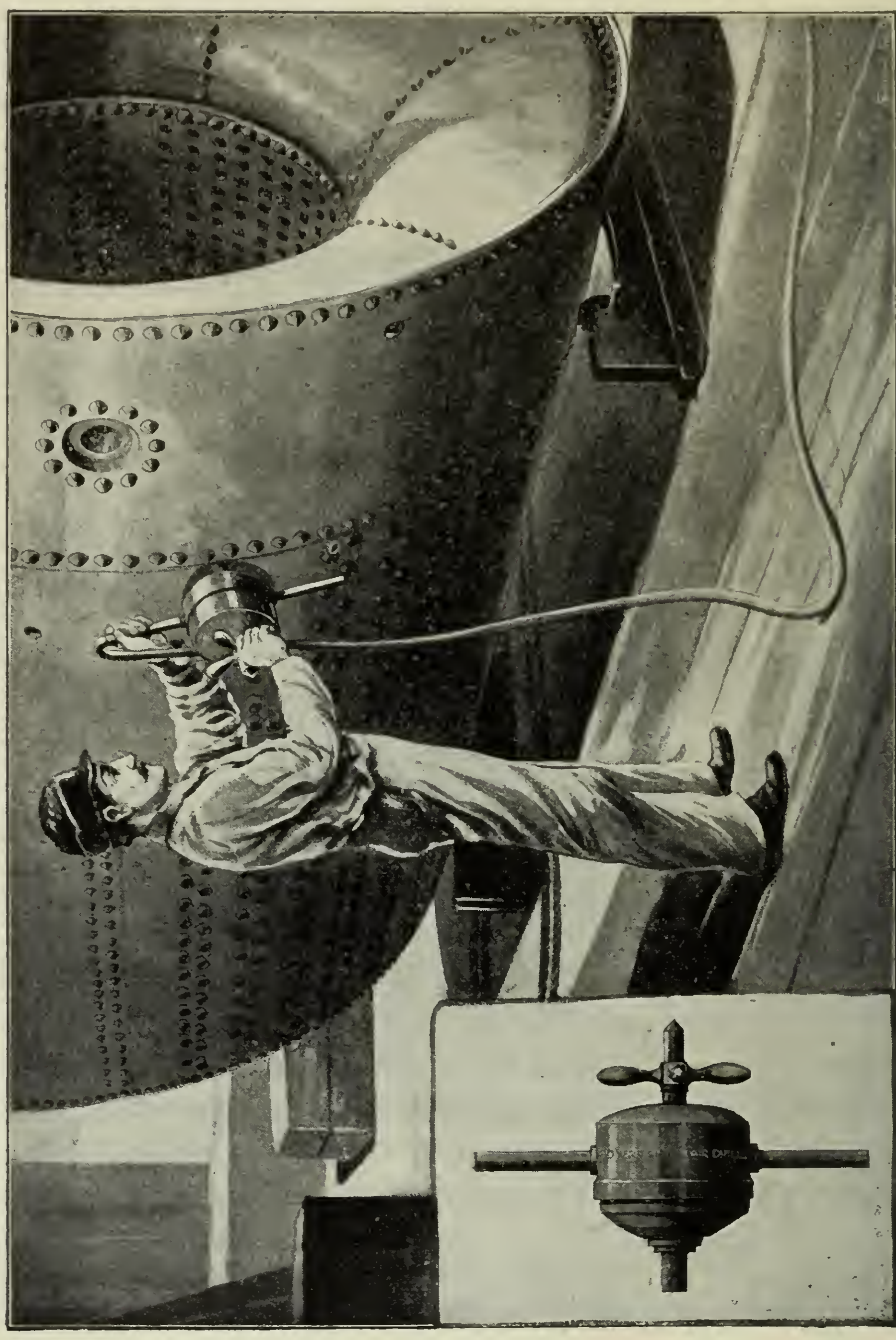


FIG. 27.—The piston air drill, for tapping, drilling, reaming, and rolling flues.

The manipulation of the car is simplicity itself, requiring no special skill or training to handle with perfect facility,

and capable of being moved in either direction as little as 2 inches.

It is perfectly noiseless, odorless, and entirely free from

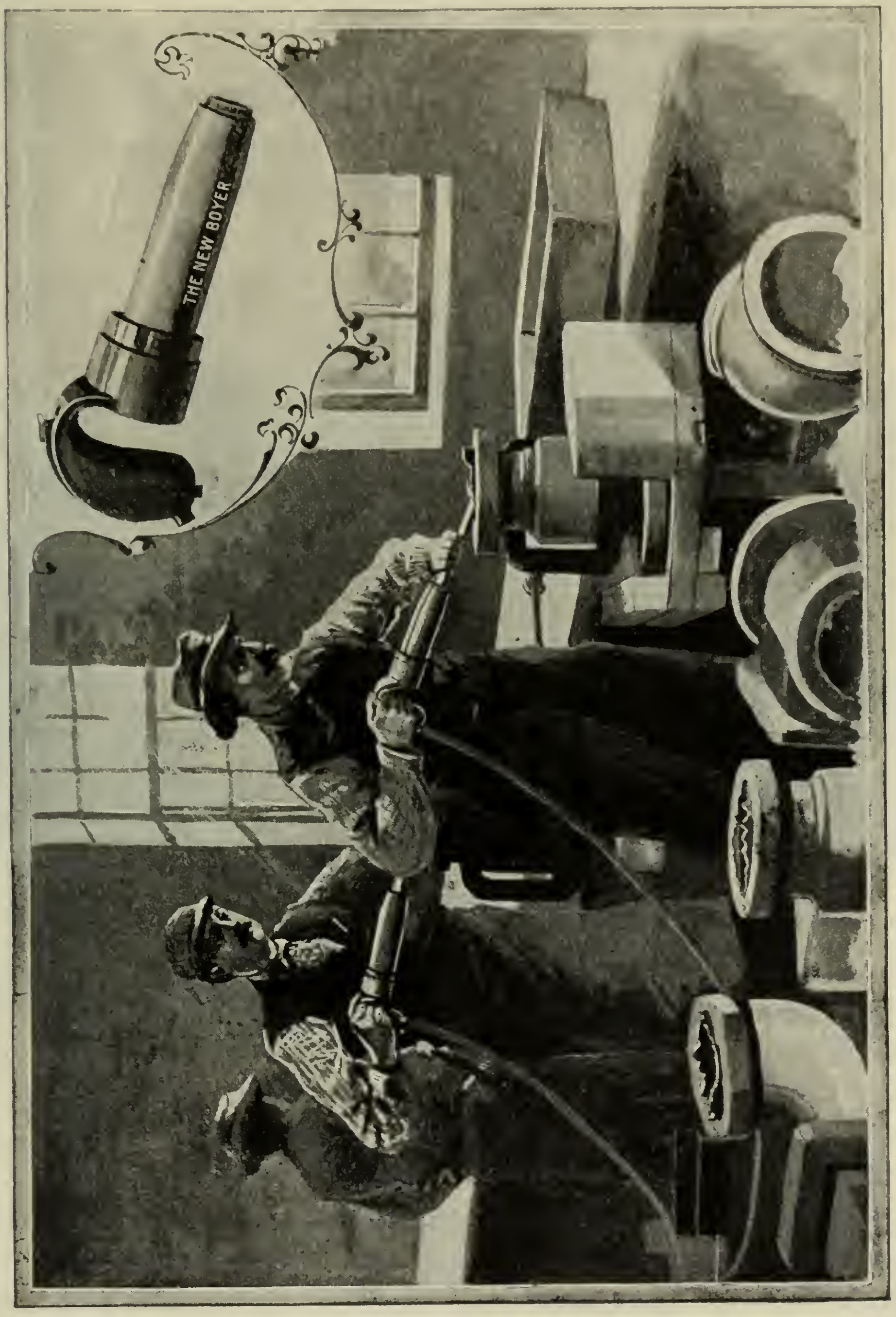


FIG. 28.—Chipping iron and steel castings.

any other offensive feature, sending neither smoke nor steam into the air. It responds to the starting and stopping

devices with remarkable promptness, operating without any jerks or jars.

This feature of easy and perfect control seems to me to be the most vital point in its relation to the public; as in other respects (freedom from the element of danger to the public as a manifestation of power), its non-hazard superiority is easily demonstrated. The ease and infallibility of control excels that of any other system known to the writer for street railways, and can never fail so long as the car has ability to move.

The car is fitted with specially designed air-brakes of sufficient power, with the high-pressure air always at com-

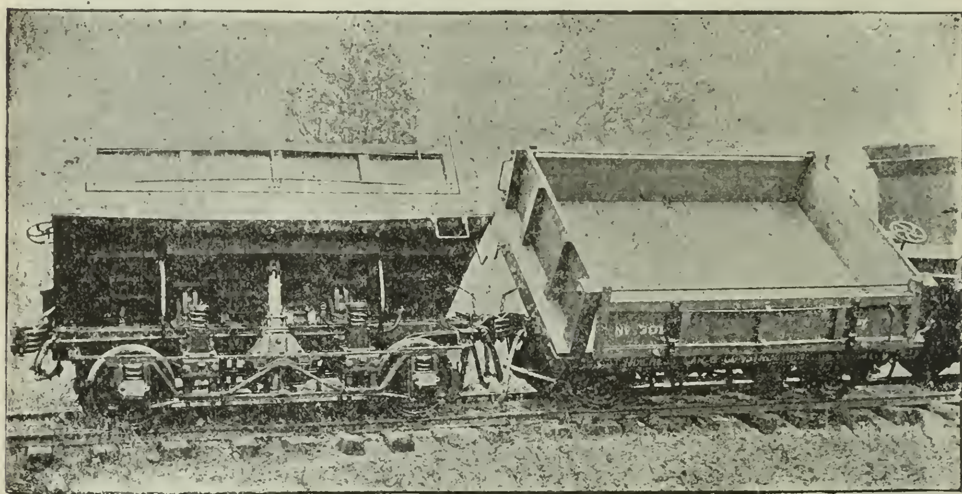


FIG. 29.—Pneumatic car dump.

mand, to set the wheels instantly if desired, by a single wrist movement of the motorman. Upon releasing the brakes there is an entire absence of noise of any kind from either the mechanism or escaping air, which is so noticeable and annoying with air-brakes generally.

The same lever that releases the brakes operates, by a slight advancing movement on the quadrant, to open a by-pass admission of the compressed air, directly into the cylinders of the motors, enabling them to start easily and positively, whatever the position of the cut-off valves may be, and preventing any possibility of being stopped on "dead centers," after which the throttle is opened. This ability to

start so promptly and surely under all conditions is a feature possessed by no other reciprocating motor, and the inability to overcome this difficulty has been one of the principal causes of failure in kindred types of motors heretofore exploited. The application of the principle of a by-pass admission of air into the cylinder seems to be confined exclusively to the motors of the General Compressed Air Company, and is of the greatest importance, materially affecting the economic operation of the motors, aside from assuring their infallibility in starting.

FIG. 30.—Wood boring.

The entire system embodying the mechanism and method of developing and applying the power, for the purposes under consideration, consists of simple, practical devices, operating on the most approved principles, from which all offensive and uneconomic features have been eliminated and better fulfilling the requirements of an ideal means of street car propulsion than any other within the writer's knowledge.

Following are illustrations given with titles only of other important applications of compressed air, detailed descriptions of which may be obtained from the files of a little paper which I publish called *Compressed Air.*

Compressed air is also usefully applied for locomotive

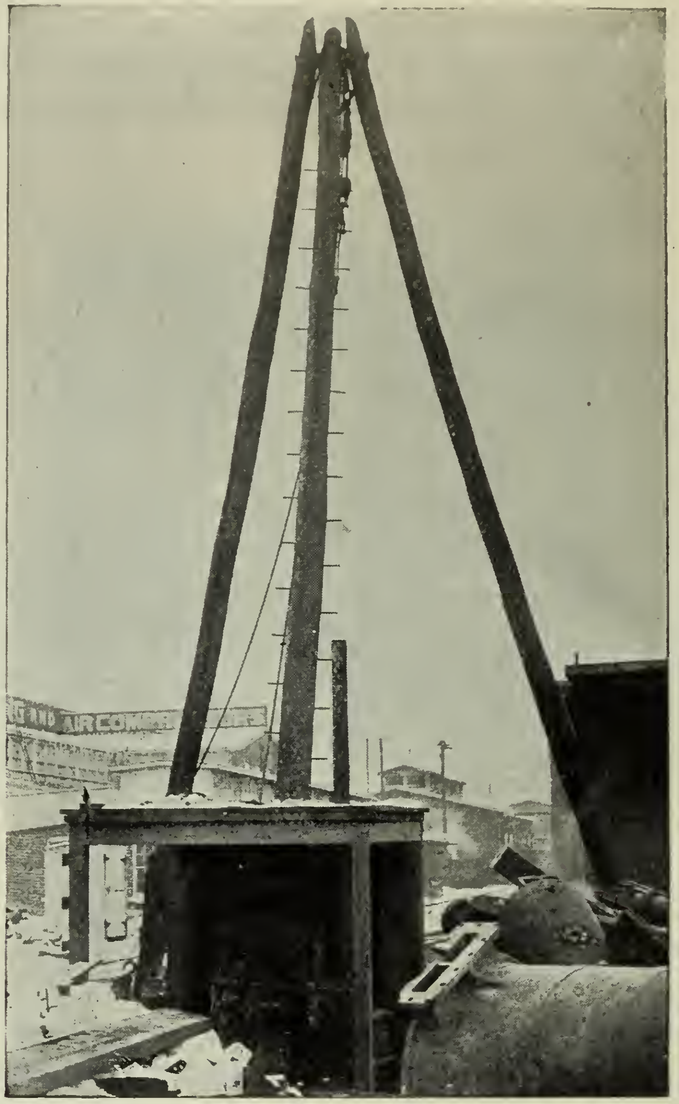


FIG. 31.—Pneumatic motor on apparatus for breaking scrap.

bell ringing, tinware presses, elevator door openers, the artist's air brush, fire-alarm whistle, shaking grates, steam hammers, hydro-pneumatic cranes, hydraulic pressure relief, wood-pulp machines in paper mills, ice making, lard refining, dentist tools, medical spray apparatus, pneumatic tires,

pneumatic beds and cushions, mixing and cooling nitro-glycerine, pile driving, pneumatic ejector, pneumatic presses, the straightening press, pipe bending apparatus, spraying colors in pottery work, whitewashing, raising metal to cupolas in foundries, removing scale from steel or iron

FIG. 32.—Caulking a pipe line.

plates, flue cleaning, steering ships, boring, drilling and finishing stone, elevating sand and water in stone sawing, tapping iron furnaces, testing brakes, pneumatic guns for throwing dynamite, raising pressure of natural gas, oil well

pumping, locomotive service in mines and docks, freezing quicksand, belt shifting, derricks, central pneumatic system of lubrication, liquid air, ditching machinery, combined with oil or gas for engine power driving, glass blowing, dredging, flue welding, grouting apparatus, horse collars, hose press, refrigerating and cooling, moulding machines in foundries,

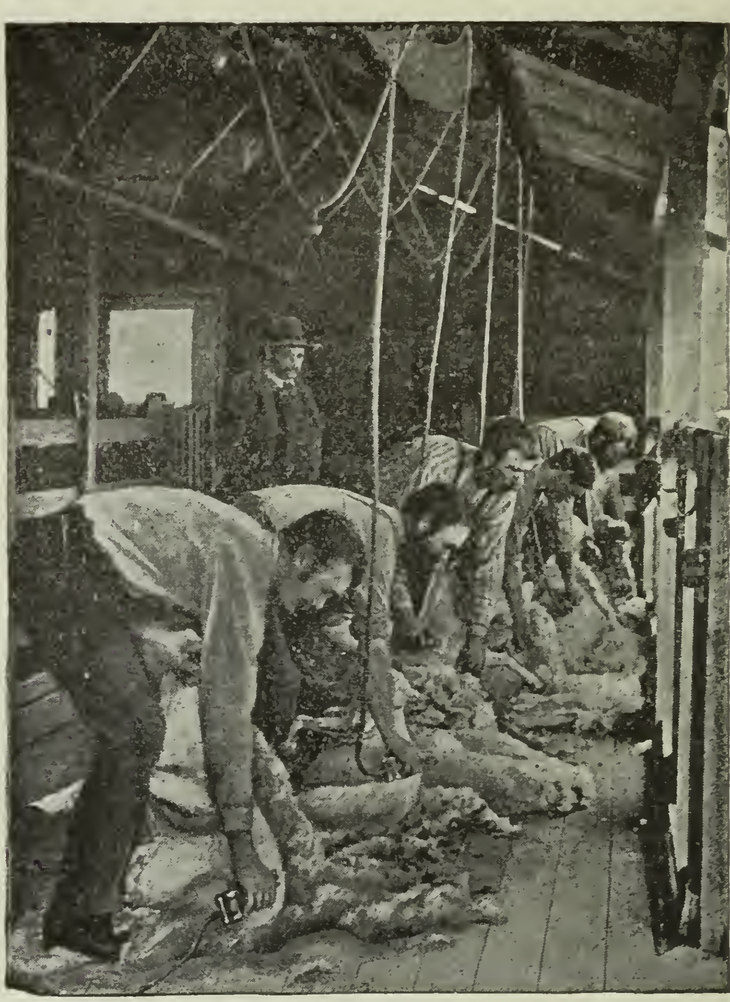


FIG. 33.—Sheep shearing in Australia.

purifying water, blacksmith forges, creating forced draughts in boilers and furnaces, copying press, disappearing gun carriage, ringing chime bells, stone-channelling machines, coal cutters, pneumatic switch and signal service, car signal on train, satin finish on metal work, kindling fires, grain elevators, dampening in laundry work, diving armor, sewage

disposal, driving motors or air engines of various kinds, clipping horses, coal or culm conveyors, lighting, agitating syrup in sugar refineries, beating eggs, raising beer, automatic fire-extinguisher service, propelling torpedoes and torpedo boats, sand-papering, aërating fuel, refining asphalt, excavating cesspools, finishing silk ribbon, for dry dock and canal lock service, agitating acids, ventilating in mines, cotton compresses, vulcanizing wood, temperature regulators, raising sunken vessels, driving printing presses and other individual tools, operating clocks, etc.

CHEMICAL SECTION.

Stated Meeting, held February 18, 1899.

THE LABORATORY PRODUCTION OF ASPHALTS FROM ANIMAL AND VEGETABLE MATERIALS.*

BY WM. C. DAY.

By carrying out operations of distillation at the ordinary atmospheric pressure upon animal and vegetable matter, both separately and mixed, I have succeeded during the past year in producing three different materials, all of which present in different degrees the properties characteristic of asphalts. Two of these materials quite closely resemble asphalts occurring in nature, namely, gilsonite and elaterite, as found in Utah.

Postponing for the present a consideration of the reasons which led to these experiments, I will first give a description of the work done and a statement of the results obtained since the publication last summer of a preliminary paper† on the same subject.

The first experiment was to distil from an iron retort a mixture of fresh fish (herring from the Delaware) and fat pine wood, partly in the form of sawdust and partly in

* Published by permission of the U. S. Geological Survey.
† "Proc. Amer. Philos. Soc.," **37**, 171.

sticks. The retort was connected with a short glass tube by means of a joint of plaster-of-paris and asbestos; this tube was connected at the other end by a similar joint with a small iron gas pipe four feet long, placed upon a combustion furnace, by which it could be maintained at a red heat. The retort was heated by gas furnaces and the distillation was carried to complete carbonization of the organic matter. An ordinary Liebig's condenser served to condense the mixed oil and water as it issued from the red-hot gas pipe. The distillation product consisted of water of a yellowish-red color, and a dark, nearly black, mobile oil, which for the greater part floated upon the water, although toward the close of the distillation a little oil would usually sink through the water.

Twelve operations of distillation consumed 9,882 grams of wood and 8,170 grams of fish, and yielded 3,010 cubic centimeters oil, of specific gravity 0·9837, and 8,240 cubic centimeters water. The average distillation shows, therefore, the figures 823·5 grams wood, 680·8 grams fish, 250·8 cubic centimeters oil and 686·7 cubic centimeters water; these average figures were approximated in each single distillation.

The oil was separated from the water and then dried by standing over chloride of calcium. A combustion of this oil, using copper oxide and lead chromate, gave the following results:

0·3104 gram oil gave 0·9593 gram CO_2 and 0·2794 gram H_2O, or

	Per Cent.
Carbon	84·28
Hydrogen	10·00

The dried oil was then subjected to distillation by itself in a hard glass retort provided with thermometer. A few drops of oil, accompanied by a little moisture, came over at 80° C.: the temperature rose rapidly to 120°, at which point distillation proceeded rapidly, giving a distillate lemon yellow in color and slightly turbid from moisture. The receiver was changed at 180°, when the distillate appeared darker in color but free from moisture. The receiver

was changed at 245°, 315° and 340°, at which last point the thermometer was removed; after this the distillation was conducted to about 425° as nearly as could be judged by the rate at which the temperature had been rising. At 315° a greenish fluorescence appeared. When the boiling was stopped the contents of the retort consisted of a mobile, homogeneous, black liquid containing no solid particles of any kind. When the retort cooled this oil solidified to a black, shining mass, showing conchoidal fracture, brittle and pulverizing to a brownish-colored powder slightly darker than the powder of Utah gilsonite, which, in appearance, it closely resembled; in fact, it was only by the rounded surface of the artificial product that the two could be distinguished by inspection. A number of distillations were made with essentially the same experience as just described, except that the material obtained the first time was slightly sticky to the touch and entirely soluble in carbon bisulphide, while the samples obtained subsequently were not at all sticky, and were not entirely soluble in the bisulphide.

Subjected to combustion, the sample resulting from the first distillation gave the following result: 0·2211 gram substance gave 0·7100 gram CO_2 and 0·1540 gram H_2O, or

	Per Cent.
Carbon	87·57
Hydrogen	7·74

Two combustions of the artificial gilsonite finally made in quantity gave the following results:

I. 0·2529 gram substance gave 0·8031 gram CO_2 and 0·1599 gram H_2O.

II. 0·3015 gram substance gave 0·9564 gram CO_2 and 0·1938 gram H_2O.

	I. Per Cent.	II. Per Cent.
Carbon	86·61	86·51
Hydrogen	7·02	7·10

Two nitrogen determinations by Kejhldahl's method, using in the first case 1·1990 grams substance, and in the second 0·9824, gave nitrogen 1·95 and 1·86 per cent., respectively.

Two determinations of sulphur by Peckham's method* resulted as follows:

I. 2·0218 grams substance gave 0·0136 gram $BaSO_4$.

II. 1·9988 grams substance gave 0·0114 gram $BaSO_4$.

	I. Per Cent.	II. Per Cent.
S =	0·092	0·078

According to the figures obtained, the composition of the artificial gilsonite appears to be as follows: For the sake of comparison, the figures for natural Utah gilsonite are also given here, as well as elsewhere.

	Artificial. Per Cent.	Natural. Per Cent.
Carbon	86·56	85·83
Hydrogen	7·06	10·59
Nitrogen	1·91	2·59
Sulphur	0·08	0·26
Oxygen (by dif.)	4·39	0·63
		Ash, 0·10
	100·00	100 00

While the differences in composition between these two materials are not great, still they can by no means be regarded as insignificant, particularly as regards those in the cases of hydrogen and oxygen. It is true, however, that much greater differences between two natural asphalts taken from sources in the same neighborhood have been found.

Determinations of solubility in the following solvents were made: Carbon bisulphide, turpentine, ether, gasoline and absolute alcohol. The method employed was to treat a weighed portion of the substance with the solvent until no further action took place, and then weigh the undissolved residue on a tared filter.

CARBON BISULPHIDE.

I.

Weight of substance taken	0·5505
" " undissolved residue	0·1060
" " dissolved substance	0·4445

Per cent. soluble in CS_2 = 80·74.

Journal Soc. Chem. Ind.*, **16, No. 12, 1897.

II.

Weight of substance taken	0·6970
" " undissolved residue	0·1293
" " dissolved substance	0·5677

Per cent. soluble in CS_2 = 81·44.

TURPENTINE.

Weight of substance taken	0·9041
" " undissolved residue	0·4568
" " dissolved substance	0·4473

Per cent. soluble in turpentine = 49·47.

ETHER.

Weight of substance taken	0·5776
" " undissolved residue	0·1904
" " substance dissolved	0·3872

Per cent. soluble in ether = 67·03.

GASOLINE.

Weight of substance taken	0·5339
" " undissolved residue	0·2845
" " substance dissolved	0·2494

Per cent. soluble in gasoline = 46·71.

ABSOLUTE ALCOHOL.

Weight of substance taken	0·5547
" " undissolved residue	0·2862
" " substance dissolved	0·2685

Per cent. soluble in alcohol = 48·40.

All the solutions obtained were characterized by a more or less marked greenish fluorescence, which is also true of the natural gilsonite.

ACTION OF SOLVENTS.

Solvent.	Utah Gilsonite.		Artificial Gilsonite.
Carbon Bisulphide	99·50	first product,	100·00
		second "	81·44
Turpentine	97·34		49·47
Ether	73·08		67·03
Gasoline	63·08		46·71
Alcohol	34·81		48·40

While the above table shows in some cases quite notable differences in solubility, every one of the solvents exercises

in each case a pronounced effect, all figures being above 30 per cent., and generally nearly 50 per cent. or more.

The action of concentrated nitric acid upon the natural and the artificial material is peculiar, and of exactly the same character. This action consists in completely dissolving the material with copious evolution of brown fumes and the production of a dark-red solution, which, upon diluting with water, yields a flocculent precipitate much resembling freshly precipitated ferric hydroxide.

In the course of an investigation of Utah gilsonite,* carried out some years since, I separated from the oils distilled from the mineral certain basic compounds suggestive in odor of the pyridine or quinoline series. These bodies were obtained by the extractive action of dilute sulphuric acid upon the oils. From such solution they are thrown down by alkalies as flocculent precipitates.

The same kind of substances were obtained from the oil which, by distillation, yielded the artificial gilsonite. The method of treatment adopted to extract these basic substances was to shake the oil with dilute sulphuric acid and then pass steam into the mixture contained in a large flask until oil no longer distilled off with steam. On neutralizing the residual acid with caustic soda solution, a precipitate looking and smelling like that from gilsonite oil was obtained. The precipitate was alternately redissolved in sulphuric acid and reprecipitated by alkali a number of times, and then, after washing with water, was left on a filter to dry. On drying, however, the material largely disappeared, thus showing its volatility, which the solid appearance when freshly precipitated had failed to suggest. It is evident, however, that the presence of these basic compounds affords another element of similarity between the natural and the artificial product, and also between these bodies and California petroleum.

DISTILLATION OF FISH ALONE.

The interesting character of the product obtained by distilling a mixture of fish and wood, and the similarity

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* *Journal Franklin Institute*, **160**, 221.

between this and Utah gilsonite, suggested the advisability of carrying out the same kind of experiments with fish alone and also with wood alone. Accordingly, a number of charges of the same kind of fish were distilled, using the same apparatus as was employed for the mixture of wood and fish.

In all 4,585 grams of fish were distilled, yielding 700 cubic centimeters of oil and 2,830 cubic centimeters water. The distillate consisted of a yellow emulsion difficult to break up; the distillate from the fish and wood mixed gave no emulsion at all, but presented a well-defined line of separation between the oil and water. The emulsion was separated into oil and water by heating upon the water-bath, the oil being eventually brought to the surface of the water. Much ammonia was produced during the distillation.

An attempt was made to dry the oil by allowing it to stand over chloride of calcium for a number of days, but it could not be perfectly dried in this way. Success in drying was finally attained only by aspirating a current of dry air through the oil while it was heated upon the water-bath.

On attempting to distil the fish oil from a retort, as was done with the oil from the mixture of fish and wood, such vigorous and explosive "bumping" was encountered as to carry the contents of the retort over mechanically so that it was found impossible to distil it in this way. The appearance of moisture during this attempt to distil an oil which had been thoroughly dried made it evident that the water was formed during the distillation. The oil was transferred from the retort to an iron crucible and heated cautiously until the stage of water formation was passed, and then heated more strongly. After heating for a time the contents of the crucible were allowed to cool, when a very sticky, thick semi-liquid mass remained. It looked and smelled more like a maltha from Montana that I had examined a few years since than anything else I could compare it to. The material was again heated in the crucible, boiling it freely; on cooling again a solid was obtained, black in color and elastic, so that if bent nearly double it would fly back to its original shape like a thick piece of India rub-

ber. It could be easily cut, but not pulverized, although if struck a blow with a hammer it would break with conchoidal fracture.

Determinations of carbon, hydrogen and nitrogen were made with the following results:

I. 0·2366 gram substance gave 0·6638 gram CO_2 and 0·1933 gram H_2O.

II. 0·2333 gram substance gave 0·6618 gram CO_2 and 0·1916 gram H_2O.

III. 0·2233 gram substance gave by Kejhldahl's method ammonia corresponding to 4·19 per cent. of nitrogen.

IV. 0·8896 gram substance gave ammonia corresponding to 4·27 per cent. nitrogen.

V. 2·0402 grams substance gave 0·0287 gram $BaSO_4$.

VI. 1·9954 grams substance gave 0·0276 gram $BaSO_4$.

	I.	II.	III.	IV.	V.	VI.
Carbon	76·51	77·36	—	—	—	—
Hydrogen	9·08	9·12	—	—	—	—
Nitrogen	—	—	4·19	4·27	—	—
Sulphur	—	—	—	—	00·19	00·19

This material, if cooled down, became harder and less susceptible of bending; the same kind of change seemed to result also as the material became older, as after some months it became harder and more brittle.

The following results of analysis were obtained upon a sample of elaterite from Utah. This material in lump form was hard and not at all capable of being bent; it was, however, quite flexible when sawed into thin slabs. The percentages of carbon and hydrogen found are not far removed from those of the asphalt from fish alone.

I. 0·2993 gram substance gave 0·8024 gram CO_2 and 0·2550 gram H_2O.

II. 0·1995 gram substance gave 0·5404 gram CO_2 and 0·1698 gram H_2O.

	I.	II.
Carbon	73·11	73·88
Hydrogen	9·46	9·45

Further investigation of this material is now being carried out. According to Dana's "Mineralogy," p. 734, elaterite analyzed by Johnston contains 84 to 86 per cent. car-

bon, and 12·3 to 13·2 per cent. hydrogen. I am unable to give the authority for calling the Utah material elaterite, but in composition it evidently resembles much more nearly the material obtained from fish than it does the elaterite described by Dana. The much lower percentage of carbon than is contained in gilsonite is noteworthy.

Treatment of oil obtained from fish alone with dilute sulphuric acid gave a solution of basic nitrogen compounds which could be precipitated by alkalies, just as in the case of oil from natural or artificial gilsonite. The odor of these basic substances was of the same character, whatever the source.

The following determinations of the solubility of the asphalt from fish alone were made:

CARBON BISULPHIDE.

Weight of substance used	0·2999
" " " undissolved	0·0954
" " " dissolved	0·2045

Per cent. soluble in CS_2 = 68·19.

TURPENTINE.

Weight of substance used	0·3163
" " " undissolved	0·1665
" " " dissolved	0·1498

Per cent. soluble in turpentine = 47·36.

ETHER.

Weight of substance used	0·2662
" " " undissolved	0·1087
" " " dissolved	0·1575

Per cent. soluble in ether = 59·17.

GASOLINE.

Weight of substance used	0·3733
" " " undissolved	0·2419
" " " dissolved	0·1314

Per cent. soluble in gasoline = 35·19.

ABSOLUTE ALCOHOL.

Weight of substance used	0·4239
" " " undissolved	0·2074
" " " dissolved	0·2165

Per cent. soluble in alcohol = 51·07.

DISTILLATION OF WOOD ALONE.

The same kind of rich and heavy pine as was used in mixture with fish was subjected to distillation by itself. In all 4,588 grams were used, yielding 1,150 cubic centimeters of oil and 890 cubic centimeters water.

It is interesting to note here the much larger proportion of oil obtained than resulted from the distillation of fish alone. The distillation was accompanied by the production of a thick, white smoke, which could not be condensed. The distillate was strongly acid. The oil, after drying, showed a specific gravity of 0·992. It was subjected to distillation by itself, collecting the same fractions as were taken in the case of the distillation of oil from wood and fish. The first fraction, 90° — 145°, was light-yellow in color, and slightly turbid from moisture; the second, 145° — 180°, was darker yellow; the third, 180° — 245°, was greenish-black; the last one showed green fluorescence. After distilling off somewhat more than half the oil, the black, but perfectly mobile liquid, was allowed to cool, when it solidified to a black shining mass, very brittle and showing conchoidal fracture. While the general color was black, inspection of a thin edge along a line of fracture showed a purple color, such as could not be seen with the material from wood and fish. The specific gravity was found to be 1·0825.

When pulverized, the powder, in the course of several days, would cement together and re-form a hard, rigid mass.

Determinations of carbon, hydrogen and nitrogen gave the following results:

0·2078 gram substance gave 0·6568 gram CO_2 and 0·1549 gram H_2O.

0·9362 gram substance gave ammonia corresponding to 0·26 per cent. nitrogen.

0·8884 gram substance gave ammonia corresponding to 0·33 per cent. nitrogen.

Determinations of sulphur gave only traces.

	Carbon.	Hydrogen.	Nitrogen.
I.	86·20	8·28	—
II.	—	—	0·26
III.	—	—	0·33

The following determinations of solubility were made:

CARBON BISULPHIDE.

I.

Weight of substance used	0·3604
" " " undissolved	0·0050
" " " dissolved	0·3554

Per cent. soluble in CS_2 = 98·61.

II.

Weight of substance used	0·3868
" " " undissolved	0·0003
" " " dissolved	0·3865

Per cent. soluble in CS_2 = 99·92.

TURPENTINE.

I.

Weight of substance used	0·4498
" " " undissolved	0·0155
" " " dissolved	0·4343

Per cent. soluble in turpentine = 96·55.

II.

Weight of substance used	0·4218
" " " undissolved	0·0167
" " " dissolved	0·4051

Per cent. soluble in turpentine = 96·04.

ETHER.

I.

Weight of substance used	0·3589
" " " undissolved	0·0153
" " " dissolved	0·3436

Per cent. soluble in ether = 95·45.

II.

Weight of substance used	0·4084
" " " undissolved	0·0130
" " " dissolved	0·3954

Per cent. soluble in ether = 96·81.

GASOLINE.

I.

Weight of substance used	0·5342
" " " undissolved	0·0441
" " " dissolved	0·4901

Per cent. soluble in gasoline = 91·74.

II.

Weight of substance used	0·3582
" " " undissolved	0·0412
" " " dissolved	0·3170

Per cent. soluble in gasoline = 88·49.

ALCOHOL.

Weight of substance used	0·5548
" " " undissolved	0·2130
" " " dissolved	0·3418

Per cent. soluble in alcohol = 61·60.

High solubility is characteristic of this material in all cases.

A quantity of the oil from wood alone was treated with dilute sulphuric acid for the purpose of testing for basic oils. No trace of these oils could be precipitated, however, by neutralizing the acid with sodium hydroxide.

In connection with the present investigation a complete analysis of Utah gilsonite has been made with results that are somewhat lower in carbon and in sulphur than those obtained and published a few years since.* Instead of using finely-powdered lead chromate together with copper oxide, as was the case in the first analysis, a large quantity of coarse granules of lead chromate were employed with results that showed better agreement.

In this connection it should be remarked that the use of copper oxide in hydrocarbon combustions has not infrequently given trouble in the form of irregularities in the figures for carbon. Professor Peckham, in a recent conversation, called my attention to a remark made to him by Warren to the effect that copper forms carbides which are oxidized with difficulty, and hence, according as these are formed or oxidized in succeeding combustions, the figures for carbon will vary. This point is now being investigated. Certain it is, however, that asphalts are troublesome substances in elementary analysis. This statement is thoroughly borne out by a study of the literature of these bodies.

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* *Journal Franklin Institute*, **160**, 221.

The following are the results of analysis of Utah gilsonite:

I. 0·2738 gram substance gave 0·2603 gram H_2O and 0·8631 gram CO_2.

II. 0·2017 gram substance gave 0·1930 gram H_2O and 0·6336 gram CO_2.

III. 1·0347 grams substance gave ammonia by Kejhldahl's method corresponding to 2·65 per cent. nitrogen.

IV. 0·9363 gram substance gave ammonia corresponding to 2·53 per cent. nitrogen.

V. 2·1651 grams substance gave 0·0390 gram $BaSO_4$.

VI. 2·0017 grams substance gave 0·0388 gram $BaSO_4$.

	Carbon.	Hydrogen.	Nitrogen.	Sulphur.
I.	85·98	10·56	—	—
II.	85·67	10·62	—	—
III.	—	—	2·65	—
IV.	—	—	2·53	—
V.	—	—	—	00·25
VI.	—	—	—	00·27

Taking the averages of these results, the percentage composition appears to be:

Carbon	85·83
Hydrogen	10·59
Nitrogen	2·59
Sulphur	00·26
Oxygen (by dif.)	·63
Ash*	·10
	100·00

*Quoted from paper on gilsonite, *Journal Franklin Institute*, **160**, 221.

TABLE GIVING ANALYTICAL RESULTS.

Name of Substance.	Carbon.	Hydrogen.	Nitrogen.	Sulphur.	Oxygen.	Ash.
Oil from fish and wood	84·28	10·00	undtm.	undtm.	undtm.	none
Artificial gilsonite from first preparation	87·57	7·74	"	"	"	"
Artificial gilsonite made finally	86·56	7·06	1·91	0·08	4·39	"
Utah gilsonite	85·83	10·59	2·59	0·26	0·63	0·10
Asphalt from fish alone	76·93	9·10	4·18	0·19	9·60	none
Utah elaterite	73·11	9·45	1·90	3·17	12·37	trace
Alphalt from wood alone	86·20	8·28	0·29	trace	5·23	none
Utah nigrite	83·33	8·69	undtm.	0·42	undtm.	0·12

	Fixed Carbon.	Volatile Matter.	Ash.
Utah nigrite	36·33	63·55	0·12

The specific gravities of various substances, determined in the course of the present investigation, are given in the following table:

SPECIFIC GRAVITIES.

Oil obtained from primary distillation of fish and wood, temperature 26° C.	0·9837
First fraction of above oil, 80–145° C. when distilled by itself, temperature 25·8° C.	0·842
Last fraction in same distillation, 340° C., temperature 25·9° C.,	1·002
Utah gilsonite, temperature 26° C.	1·0354
Artificial gilsonite, temperature 26° C.	1·1713
Asphalt obtained from wood alone, temperature 26° C.	1·0825
Alphalt obtained from fish alone, temperature 26° C.	1·0590
Oil from wood and fish, vo.atile with steam, temperature 26° C.,	0·8940
Oil obtained in primary distillation of wood, temperature 26·4° C.	0·9920

TABLE OF SOLUBILITIES IN VARIOUS SOLVENTS.

Name of substance.	Carbon Bisulphide, all.*	Turpentine.	Ether.	Gasoline.	Absolute Alcohol.
Artificial gilsonite	81·09	49·47	67·03	46·71	48·40
Utah gilsonite	99·50	97·34	73·08	63·08	34·81
Asphalt from fish alone	68.19	47·36	59·17	35·19	51·07
Asphalt from wood alone	99·26	96·29	96·13	90·12	61·60

* This determination involved no weighings, as when the solution was filtered nothing insoluble remained behind on the filter.

The foregoing experiments suggested themselves as the result of a number of years of experimental work upon asphalts from a number of natural sources in the Western part of the United States and a study of the literature of natural hydrocarbons, solid, liquid and gaseous, and the synthetical experiments which have been carried out by Warren, Engler and Sadtler. From the chemical-geological standpoint the writings of Peckham have been very suggestive, advocating, as they have done, the idea that bitumens are distillates together with water of organic matter, which has accumulated in strata of all ages in the earth.

Utah gilsonite is the natural material to which the writer has given most experimental study. This mineral contains very little oxygen and sulphur, almost no ash, but a notable quantity of nitrogen, which shows itself in distillation pro-

ducts in the form of basic substances similar in a general way to the pyridine and quinoline series, and of the same character as the basic substances obtained by Peckham and Salathé from California petroleum, and freely commented upon by Peckham in a number of papers by him.

These nitrogen compounds suggest animal origin of the bodies containing them. It seemed, however, to the writer that a material having exclusively animal origin would be likely to contain a larger proportion of oxygen than is contained in such material as natural gilsonite, and that in laboratory experiments to reproduce asphalts low in oxygen, vegetable material should be present at the same time, and that opportunity should be afforded for the oxygen containing distillates from oils and animal substances to react at a fairly high temperature with the abundant gaseous hydrocarbons produced by distilling wood or in general vegetable material. The result of such reaction between bodies of the nature just described would be to eliminate oxygen from the oily distillate by causing it to form water and carbon dioxide with the hydrogen and carbon of gaseous hydrocarbons. This idea was strengthened by the fact that in his experiments to produce petroleum-like substances and paraffine from linseed oil Sadtler * noticed the odor of acrolein and referred to it as follows: "At first the odor of acrolein was very pronounced and powerful, showing that the glycerine of the glycerides composing the oil was being decomposed; later the odor was more that of a cracked petroleum oil, showing that the linoleic and other aids of the oil were undergoing decomposition." On another page the same writer says: "Of course the fractions must be obtained on a sufficiently large scale to admit of thorough purifying before the character of the hydrocarbons can be studied. At present they contain impurities, such as aldehyde-like and possibly ketone products. They reduce ammoniacal silver solutions and indicate thus the presence of these impurities."

The following facts, based upon a consideration of the

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* "Proc. Amer. Philos. Soc.," **36**, 93.

character of the distillates obtained from the mixed animal and vegetable matter, the fish alone and the wood alone, tend to show the correctness of the writer's position in an attempt to produce an asphalt low in oxygen. The table of ultimate analyses given below shows that there is less than half as much oxygen in the asphalt from wood and fish mixed as in that from fish alone.

ULTIMATE ANALYSES.

	Ash.	Carbon.	Hydrogen.	Sulphur.	Nitrogen.	Oxygen.
Utah gilsonite . . .	0·10	85·83	10·59	0·26	2·59	0·63
Utah elaterite . . .	—	73·49	9·46	undtm.	undtm.	17·05
Artificial gilsonite from wood and fish . .	—	86·56	7·06	0·08	1·91	4·39
Asphalt from wood .	—	86·20	8·28	trace	0·29	5·23
Asphalt from fish . .	—	76·93	9·10	0·19	4·23	9·55

The following table, giving the yields of water and oil in the various distillations, is also of interest, as showing the effect of water forming reactions between hydrocarbons and oxygen compounds, which, doubtless, took place in the hot tube through which the vapors were passed before condensation.

Material Used, Grams.		Oil Produced, Cubic Centimeters.	Water Produced, Cubic Centimeters.
Wood.	Fish.		
9,882	8,170	3,010	8,240
—	4,585	700	2,830
4,588	—	1,150	890

If the wood and fish, when distilled together, had yielded oil and water in the same proportion as when each was distilled by itself, then there should have been a yield of 3,724 cubic centimeters of oil from the mixture, instead of the 3,010 cubic centimeters actually produced, and, instead of 8,240 cubic centimeters of water, there should have been only 7,321 cubic centimeters.

The question of the origin of asphalts is one that cannot be intelligently discussed apart from that of the origin of petroleum, or, more broadly still, apart from the origin of the bitumens in general, which include natural hydrocarbons in all states of matter, solid, liquid and gaseous. Of these three states, liquid petroleum has, for a variety of

obvious reasons, received the most attention scientifically and technologically.

The connection quite generally believed at present to exist between petroleum and the asphalts is expressed in Dana's "Mineralogy," p. 751, as follows: "The more solid kinds graduate into the pit asphalts, or mineral tar, and through these there is a gradation to petroleum. The fluid kinds change into the solid by the loss of a vaporizable portion on exposure, and also by a process of oxidation, which consists, first, in a loss of hydrogen, and finally in the oxygenation of a portion of the mass."

If it be accepted as true that petroleum and the asphalts are related, as the quotation just made would indicate, then it follows, of course, that any view as to the origin of petroleum also applies to the asphalts. A study of the literature concerning theories as to the origin of petroleum reveals a number which differ fundamentally from each other, and which are based largely upon geological evidence. It does not seem necessary here to give detailed consideration to these hypotheses in view of the thorough manner in which they have been recently summed up and reviewed by Messrs. Sadtler, Peckham, Mabery, Phillips and D. T. Day in a series of papers* read before the American Philosophical Society, February 5, 1897. The comprehensive *résumé* given by Boverton Redwood in his work on petroleum also contributes to make further detailed review superfluous at this time. It seems, however, that the propriety of attempting to make any one of these theories cover the entire question of the origin of petroleum is very questionable in view of the fundamental differences in character and properties between petroleums of different sources, which, by the work of Schorlemmer, Warren, Mabery, Beilstein and Kurbatow, Markownikoff, Schutzenberger and Jonine, Zaloziecky and others, have been shown to exist. The following quotation from Boverton Redwood's work is of interest in this connection.

Referring to his *résumé* of theories, he says: "From the

* "Proc. Amer. Philos. Soc.," **36**, 93.

account given in this section, it will be seen that there has been an abundance of speculation as to the origin of bitumen, and that, in regard to some of the theories, a considerable amount of experimental proof has been forthcoming. Probably, on the whole, the Höfer-Engler views at present have the largest number of adherents, and in respect, at any rate, to certain descriptions of petroleum, are the most worthy of acceptance. At the same time, a careful study of the subject leads to the conclusion that some petroleum is of vegetable origin, and it therefore follows that no theory is applicable in all cases."

When we consider, for example, the striking differences in character between California petroleum and Pennsylvania petroleum, to which Peckham, in a number of different papers, has earnestly called attention, the force of the last sentence quoted from Redwood will undoubtedly be keenly appreciated. Commenting upon the Höfer-Engler theory, Professor Peckham* says: "Dr. Engler, therefore, considers that some change in the animal remains must have taken place in the earth, whereby all nitrogenous and other matters, save fats, were removed, the petroleum being formed from this fat alone by the combined action of pressure and heat, or by pressure only.

"In summing up the evidence as to origin, Höfer expresses the belief that petroleum is of animal origin, and has been formed without the action of excessive heat, and observes that it is found in all strata in which animal remains have been discovered.

"Combining these two statements, we arrive at this conclusion as the Höfer-Engler theory, that bitumens are of animal origin, formed at low temperatures from fats alone by the combined action of pressure and heat.

"Steam is left out of this formula, and it is, therefore, inadequate. There is no evidence whatever that any portion of the crust of the earth has ever been subjected to the combined action of heat and pressure without the presence of steam or hot water, and in my judgment the steam has

*"Proc. Amer. Philos. Soc.," **36**, 106.

been a very potent factor in determining not only the formation, but the transference of bitumens."

The writer, from his experience in the production of asphalts, as already described in this paper, feels like endorsing most heartily the views of Peckham in regard to the necessity of steam as a factor in the production of such asphalts, at least, as have been made the subject of experimental study.

The following is a quotation from Professor Peckham's paper on "The Genesis of Bitumens as Related to Chemical Geology,"* which sums up the most important features of his views as to the genesis of bitumens. The laboratory results which I have so far obtained seem to be quite fully in accordance with the conclusions which Professor Peckham has reached.

"Upon this hypothesis, that bitumens are distillates, all of the variations observed in bitumens of different geological ages are easily explained. The earliest forms of animal and vegetable life are admitted to have been nearly destitute of nitrogen; hence, when these forms accumulated in sediments which, borne down by deposits above them, invaded an isothermal that admitted of their distillation, they must have been distilled, in the presence of steam, at the lowest possible temperature; they must have been distilled under a gradually increasing pressure, the extent of which depended upon the porosity of sediments above them up to the surface. They must also have been distilled under a gradually increasing temperature, which would have been largely controlled by the pressure. While the temperature and pressure would have, in every instance, been the least possible, with steam always present, these physical conditions would, on account of the varying porosity and consequent varying resistance of the overlying mass, have produced very great effects in some instances, and very slight effects in others. As a consequence, we have in natural bitumens, as in artificial distillates, materials varying in density from natural gas to solid asphaltum.

**Loc. cit.*

"If these distillates proceeded from materials that would yield paraffine, these permanent and stable compounds from marsh gas to solid paraffine remained in the receptacles that nature had provided for them until they were released by the drill. If, however, the distillates proceeded from sediments of a different geological age, containing animal and vegetable remains more highly organized, that would yield different series of hydrocarbons, with compounds of nitrogen, then a very different bitumen would be stored in these receptacles. Secondary reactions would convert these primary distillates into a great variety of substances.

"The contents of the original reservoirs, borne down and invaded by heat, might become involved in a second distillation at an increased pressure and temperature. Fractures of these reservoirs from excessive pressure might lead their contents to the surface along lines of contact of strata or with water containing sulphates, by which an originally pure hydrocarbon would be converted into a sulphur bitumen. A nitro-hydrocarbon, reaching the surface under these conditions, might, by the combined action of evaporation and reaction with sulphates, pass through all the varying degrees of density from petroleum to maltha, and become finally solid asphaltum, and this, through the lapse of time and abundance of material, on a scale of vast magnitude."

While it is true that most of the theories that have been advanced to explain the origin of bitumens have been directly concerned with the liquid variety ordinarily known as petroleum, and seem at least to have been based upon study, whether geological or chemical, of this variety to the exclusion of the solid form generally known as asphalt, still it is true that some theories have been advanced to explain directly the formation of asphalts, aside from and independently of their possible relation to liquid petroleums.

Thus the Trinidad asphalt was looked upon by Wall* as having resulted from the gradual decomposition of vegetable matter found imbedded in it. This view is, however,

* "Q. J. G. Soc.," **16**, 460.

no more tenable than the idea that the material originated from animal remains which have been found clearly indicated from a study of the composition of the asphalt.

When we consider the amount and the character of the strictly chemical work that has been done upon the asphalts or solid bitumens, it must be admitted that they have been decidedly neglected as compared with the liquid form. Even elementary analyses are, in many cases, unreliable, and there is much need of painstaking and persistent study in this field.

When we contemplate the marked differences between bitumens from different sources, it hardly seems reasonable to believe that any one theory as to the origin of these bodies can cover all the actual occurrences. It would seem that heat and pressure, singly and combined, and of various intensities, acting with water, both as liquid and as steam, upon the same fundamental material, whether animal or vegetable, should produce a variety of carbonaceous substances differing from each other quite profoundly in physical and chemical properties. Again, similar or identical conditions prevailing with different kinds of material, whether animal or vegetable, or mixtures of the two, should also yield products of various kinds. When, therefore, we consider the great possibilities of variation in combinations of natural forces, and also equally great possibilities of variation in the nature of the organic material upon which these forces may act, it is not surprising that we find, as we do, in various parts of the earth, complicated and intimate carbonaceous mixtures, gaseous, liquid and solid, which are usually summed up under the general heading, bitumens.

The facts and figures given in this communication speak for themselves. Summed up, they show that three asphaltic substances have been obtained by operations of distillation, primarily in presence of steam from natural animal and vegetable material, both separately and combined. The material obtained from the mixture of fish and wood, and called artificial gilsonite, so closely resembles the gilsonite from Utah that it is impossible by inspection to tell the two materials apart. The material obtained from fish alone also

resembles what has been called (with questionable propriety) elaterite from Utah. While these two pairs of substances differ from each other to a greater or less extent in respect to the various parallel treatments to which they have been subjected, and while they also differ somewhat in chemical composition, as well as in physical solubility, specific gravity, streak, etc., these differences are all *in degree* and not in any single case *in kind.*

I am now engaged in the study of an asphalt known as nigrite, which occurs near the gilsonite of Utah. The differences between these two bitumens are throughout more striking than any that I have observed between the natural and the artificial substances considered in this paper.

In conclusion, I take pleasure in acknowledging the benefit and the satisfaction I have derived from a study of the papers published by Professor Peckham, particularly the two entitled "The Genesis of Bitumens as Related to Chemical Geology"* and "On the Nature and Origin of Petroleum."†

I am indebted to my assistant, Mr. Eugene Leamy, for able assistance throughout the entire work, and to one of my former pupils, Miss Georgia Porter, for the nitrogen determinations.

SWARTHMORE COLLEGE, PA., February 18, 1899.

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* "Proc. Amer. Philos. Soc.," **37**, 108.

† *Ibid*, **36**, 103.

THE FRANKLIN INSTITUTE.

Stated Meeting, held Wednesday, April 19, 1899.

IMPROVED METHODS FOR THE PURIFICATION OF SEWAGE AND WATER, AS SHOWN IN THE OPERATION OF THE MUNICIPAL PLANT AT READING, PA.

By JOHN JEROME DEERY,
Architect and Engineer, Philadelphia, Pa.

The city of Reading, Pa., between 1880 and 1893 considered various propositions to provide itself with a sewerage system, which was found to be necessary by the difficulties encountered, particularly in the low sections of the city, where the seepage from the cesspools had caused trouble and disease. The usual abominations and annoyances of a cesspool city had reached that point where they must be eradicated and a modern method substituted.

In December, 1893, City Engineer S. S. Hoff was directed by the ordinances of the City Councils to prepare a statement of general conditions required, and to advertise for general drawings and specifications, and proposals to carry them into effect. These advertisements were inserted in most of the architectural and engineering journals. As an outgrowth of the request, four engineering and contracting companies complied with such invitation.

The proposals and drawings were submitted to the City Councils of Reading, in January, 1894. The various committees of that body inspected plants in other cities and towns, listened to addresses by experts upon the matter, and after careful consideration the City Councils in joint session accepted the proposition of the Pennsylvania Sanitary Sewerage Company of Philadelphia, in the latter part of March, 1894. Shortly thereafter, the pumping station and its appurtenances were placed under contract with the company. In June, 1895, an additional contract was entered into with the company, for the construction of the purifi-

cation and disposal plant, and the laying of the mains. In short, buildings, machinery, mains, right of way and site for disposal plant were provided by the company.

During 1893 the city employed Gracie S. Roberts, C.E., of Brooklyn, to design a house sewerage system, with directions that it be devised to unite with a proposed pumping station at the foot of Sixth Street. After the plans were completed, the first sewer district was placed under contract, consisting of about 3,000 feet of 54-inch brick sewer, and about twenty miles of terra-cotta pipe sewers and ten miles of terra-cotta pipe house connections. In service April, 1899, there were about twenty-six miles of mains and fourteen miles of house connections.

The general drawings, specifications and detail drawings for the pumping station, and for the purification and disposal station were prepared and designed by the writer, and the work was constructed under his supervision.

PUMPING STATION.

The sewage pumping station is located on a plot of ground on Canal Street near Sixth, and adjoining the Schuylkill River and Canal. It is the lowest point in elevation above the river level, and it enables all sewage to reach the station by gravity.

In the designing of the building and its appurtenances, the site compelled a full consideration of the economy of space and the working facilities. The building covers an area of 76 feet by 70 feet, and extends in parts 20 feet below floor level, and 37 feet above it. The structure contains an office, workroom, lavatory, oil and waste room, engine room, boiler room, coal and coke storage rooms, coke rendering room, smoke and vent stacks, and two sewage-receiving reservoirs.

The boiler room is provided with a set of three horizontal tubular boilers, each of 60 horse-power, with accompanying hot-water well and feed pumps.

The boilers are provided with the coal supply from storage room in front of them, with coal chute doors, thereby keeping coal off floor of boiler room. The coal is brought

into the building on an elevated track from the level of Canal Street, and is dropped into storage room. The boilers have down draught into a 3 x 3 feet flue beneath the floor which connects with the chimney stack. The flue is built of concrete, with a 9-inch lining of fire-brick, and is graded on bottom to the stack. Provision for cleaning out the flue has been made by a vault adjoining the stack, with a dust chamber, so that the soot may be removed

Municipal Sewage Purification Works, Reading, Pa. Pumping station.

either below or on the level of the flue with the aid of a permanent crane on stack for lifting it out.

The pump room has space provided for three 5,000,000 gallon pumps, while at present there are installed two Snow 5,000,000 gallon direct-acting, compound, condensing pumps, connected with an elongated suction chamber, 20 feet in depth, which is joined to each of the sewage-receiving reservoirs. In same room there are also installed two duplex

Municipal Sewage Purification Works at Reading, Pa. Interior of sewage-receiving reservoir, showing distributor, screening floor, air-vents, etc.

surface-condensing pumps, which draw water from a well supplied by the Schuylkill River, and also from the street water-main. The oils and wastes are housed in a non-combustible brick masonry room.

There are two sewage-receiving reservoirs, or screening chambers, each 20 feet in diameter. They are separated by the grease-rendering oven and the smoke and ventilation stack. The stack is arranged with an inner smoke flue, and with outer cluster of ventilating flues.

The sewage flows by gravity from the 54-inch sewer into and across either of the receiving reservoirs, over an open metal trough or distributor, the liquid falling in thin films upon a coke screening bed. These beds are constructed of wrought-iron slats, with upper and lower layers, holding coke breeze or coarse and medium size broken coke to a depth of 12 inches. Over the lower slats is placed a wire grating, ¼-inch mesh, of No. 12 wire. These screening beds intercept the grease and coarse floating matter, and the liquid, which is coarsely filtered, drops like rain for 7 feet in the presence of rapid circulation of air into the lower section of the reservoir, whence it flows to suction chamber. Once a week the sewage distributor is pulled, thereby flushing the sewers and depositing its filth on upper crate. After draining for a day the screens are removed in sections. The coke, with all matter adhering to it, is transferred by overhanging crane and tilting bucket into the adjoining brick steam-heated drying and rendering oven.

A constant and copious supply of fresh air is introduced into the reservoirs above and below the suspended screening beds, and it is kept in rapid circulation and removal by special ventilating passages surrounding the smoke flue of the chimney stack, and is discharged into the outer atmosphere at a height of 100 feet. There is absolutely no unpleasant or offensive odor in or around the building from the operation of the plant, and the crude house sewage is purified in these reservoirs to the extent of 25 to 30 per cent. by the aid of light, air and coke-breeze filtration.

The receiving reservoirs are lined above the suspended coke screening beds to grade with white enamelled bricks

and white tiles, and below the screens with vitrified brick, thereby preventing absorption and maintaining cleanliness.

The receiving reservoirs, or screening chambers, have large skylights for illumination and for light as an aid to purification. Appliances and bridges are arranged to facilitate inspection and provide a ready means of cleaning and maintaining the reservoirs in their proper condition. By a series of gate valves, the reservoirs may be used jointly or separately. The reservoirs are in service alternately for a week, and use 7,000 to 8,000 pounds of coke.

When all the coke and sludge matter is removed, the gratings and walls are washed from a hose provided for that purpose under the bridge. Then new coke is lowered into place to form screening bed, and upper grating is reset, as also the sewer inlet or distributor. The reservoir remains in that condition until placed in service.

The drying oven is of brick, having steam-pipes on walls and floors. Through the opening adjoining the reservoirs the coke from screening beds is placed in the ovens. When the coke is dry it is removed through lower door openings and deposited in coal storage room, and is burned as fuel in fire-boxes under the boilers. The small sizes of the coke are shovelled into bags and used as fertilizer. The oven is thoroughly ventilated by connections to the stack and to fire-boxes of boilers.

The building is fireproof in every particular. The exterior presents a pleasing architectural effect. It is faced with light-buff brick, and trimmed with moulded bricks and terra-cotta in the same color. The cornices are of copper and the roofs covered with heavy galvanized iron. The interior is finished in red brick laid in same-colored mortar. All floors are composed of concrete base and granolithic cement surface. Proper provision is made for draining all parts of the building. The earth displaced by the excavation has been formed into an embankment around the building and held in place by riprap facing and stone retaining-walls. The grounds around building are finished off with grass and flower plats. Space is provided for a driveway, which is paved with vitrified brick. All the walks sur-

rounding the building are of cement and concrete composition. A low rustic stone wall has been built along the street front of the site.

The buildings are located within 150 feet of the canal and within 250 feet of the Schuylkill River. The floor level of the buildings is eight inches above the canal level. Innumerable springs were met in the construction of the work, as well as a flood from the river. Portions of the work are constructed below the level of the bottom of the river. The receiving reservoirs have been made water-tight, preventing ground water from entering them.

PURIFICATION STATION.

The purification and disposal plant is located 6,600 feet below the pumping station at Millmont, on the opposite side of the river. The site contains eight acres, with access by lane from main road. The site is bounded by the Schuylkill River, the Angelica Creek, the Pennsylvania Railroad and the Philadelphia & Reading Railroad. The latter road has a station adjoining the property, and the former has one at Orrton, one-quarter mile from the premises.

The pumping main is of cast iron, 36 inches in diameter, crossing the bottom of the canal of the Schuylkill Navigation Company, and thence by a 30-inch main of cast iron, laid diagonally in trench across the bottom of the Schuylkill River to the opposite bank. The sizes of these mains are more than ample to permit the pumping through them of 10,000,000 gallons daily. On the other bank the plans call for two lines of 20-inch cast-iron mains, which generally follow the topography of an abandoned canal. One line of the 20-inch main has been set in place, but provision has been made for placing a second line in position when the future extensions and service may require it.

The crossing of the river by the pipe line is 450 feet in length. Trestles were built within the river and platforms placed thereon. The cast-iron pipes were floated and lifted to a point beneath the platform. While in suspension the joints were leaded in customary method, and the entire

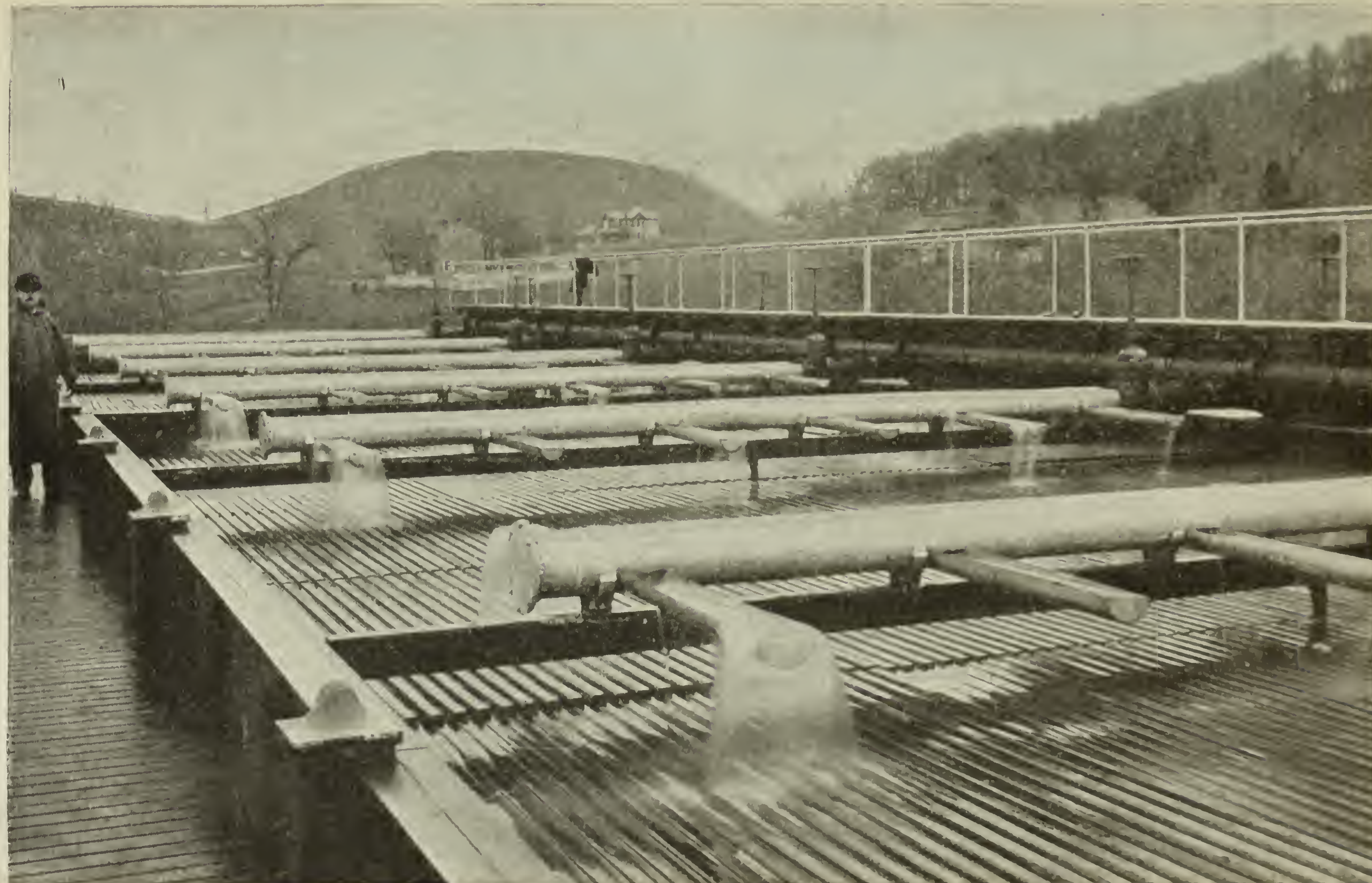
main was subsequently lowered in one length of 450 feet by having a man stationed at each joint of the pipe, who turned a swivel on signal, so that the entire length was laid as one complete pumping main.

The purification and disposal plant is designed to purify crude house sewage, excluding rain and storm water, and after partial purification in screening chambers of the pumping stations, by continuous filtering operation, with the exception of the period when it is necessary to remove the matters in suspension that are held on top of the upper filters. The entire process is based on what is classified as "Slow Sand Filtration by Gravity." It is arranged so as to obtain the purifying action of light, air and scavenger micro-organisms. In fact, it is a home for the cultivation and propagation of those organisms. At the disposal and purification station there have been constructed double filter beds having upper and lower sections with an intervening air space between them of 10 feet, the supporting and dividing parts being entirely of iron or steel.

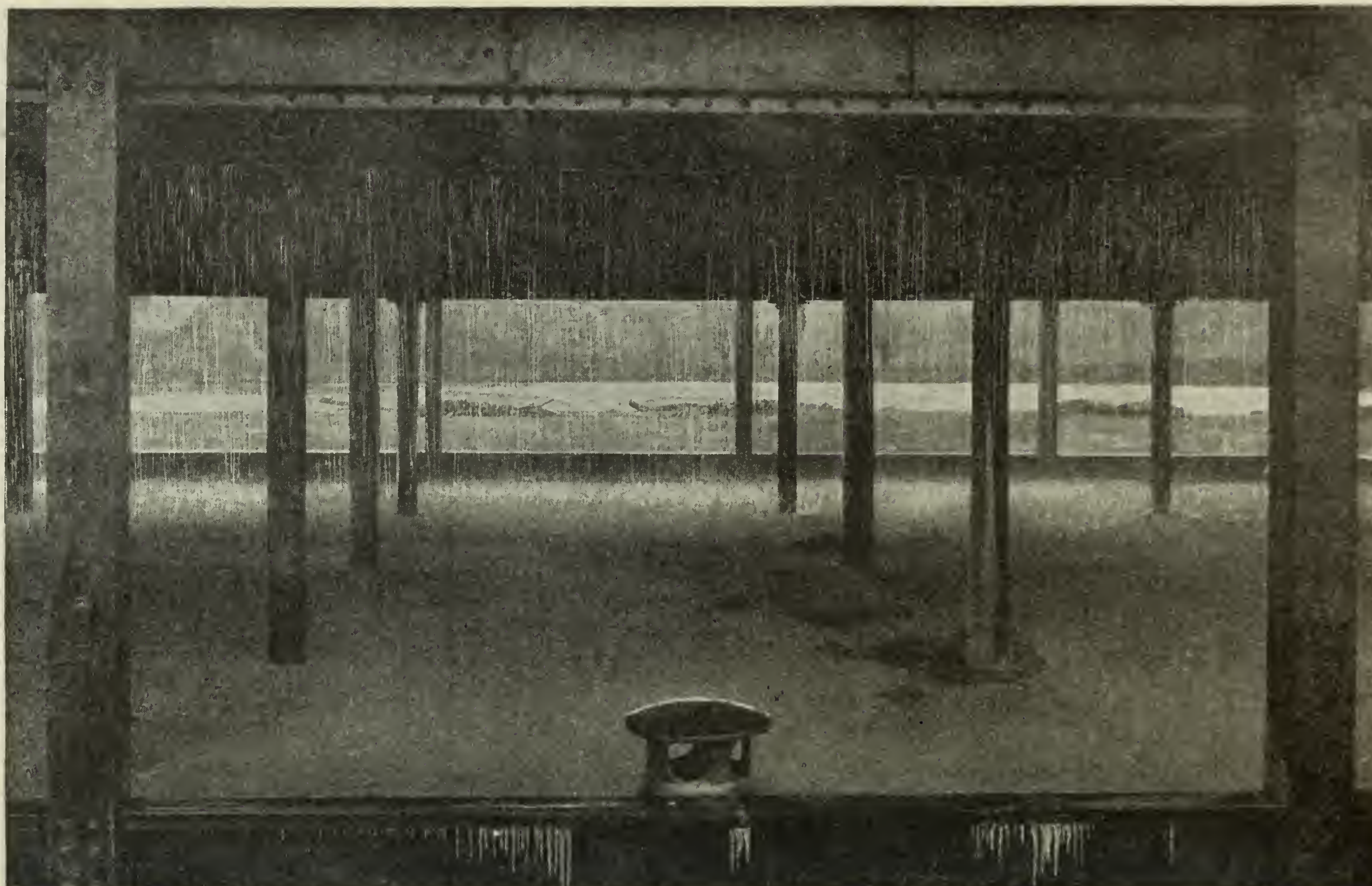
The lower filter is in one bed, 50 feet x 250 feet, formed over a cement concrete floor, with twenty channels draining the bed into a cement-constructed open effluent channel on outside of structure and parallel to it. Each gutter under beds is $7\frac{1}{2}$ inches at the bottom, 18 inches wide at the top and from 4 inches to 8 inches deep, and is covered with perforated cast-iron grates. At the upper end of each of these gutters are stand pipes extending above the surface and topped with wind guards. This arrangement ensures the circulation of the air to the lower beds and at same time conducts away the effluent. Outside of the structure in each of the twenty channels are set steel disturbers. The lower bed is enclosed with $\frac{5}{8}$-inch tank steel, with three rows of channels set horizontally and all bolted to the columns. The joints are covered at the intersection on the columns with sheet-lead gaskets.

The open effluent channel is of concrete, 4 feet wide at the bottom, 6 feet 2 inches wide at the top and 12 inches to 18 inches in depth, and for a length of 650 feet.

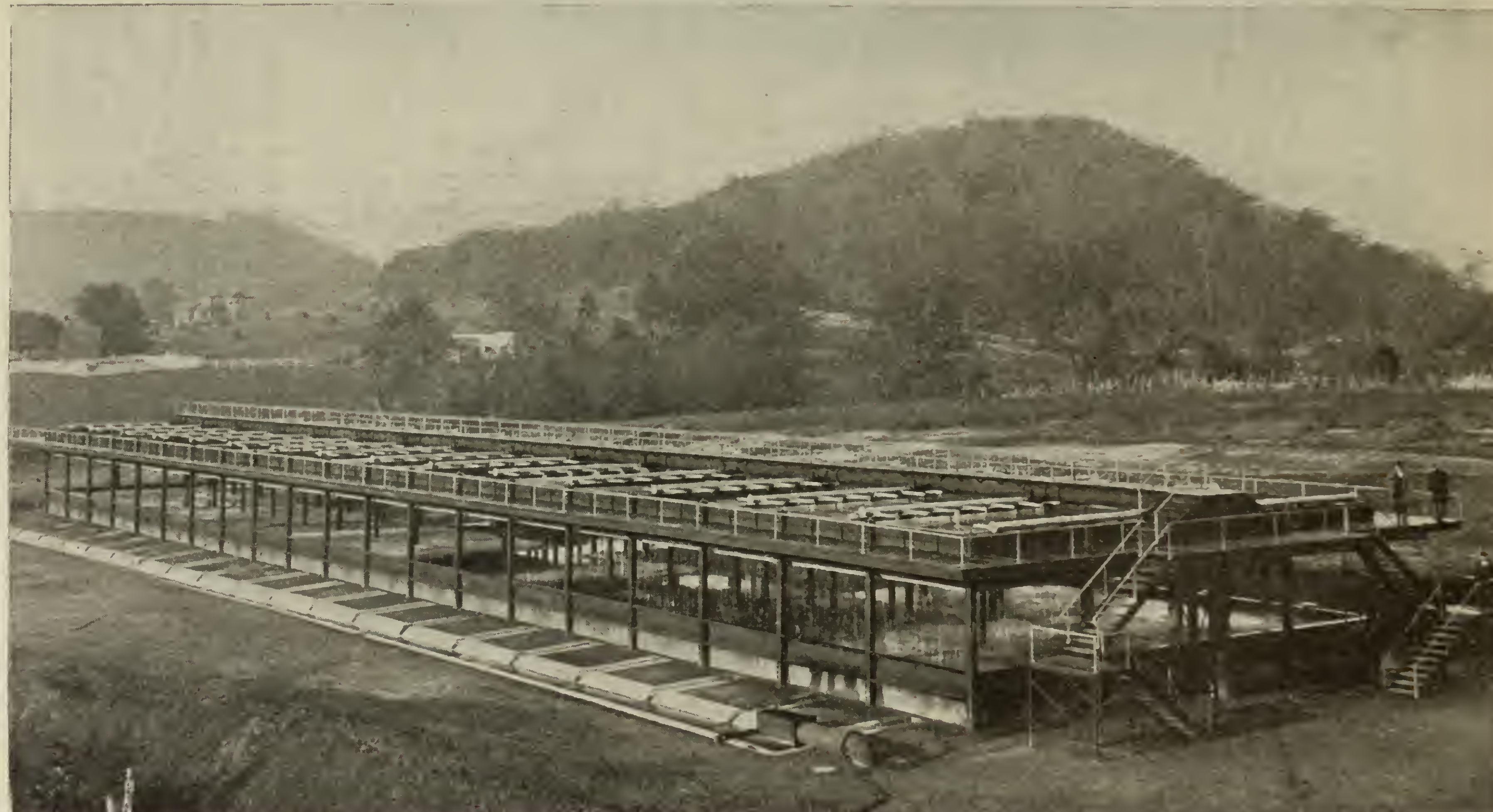
The lower filter bed has an average of 8 inches in depth



Municipal Sewage Purification Works at Reading, Pa. Surface of upper section of filter beds, showing distributors, valves, slatted screens, etc.



Municipal Sewage Purification Works at Reading, Pa. Lower section of filter beds, showing water dropping from upper beds, air circulating pipes, etc.



Municipal Sewage Purification Works at Reading, Pa. General view of filter beds, ten compartments; total capacity, 5,000,000 gallons per day.

of broken stone or slag, in layers of sizes from 2 inches to $\frac{3}{4}$ inch. Over the stone has been placed medium coarse river sand for a depth of 36 inches.

The upper filter is divided into ten compartments for cleaning and renewal purposes, each 25 by 50 feet. It is elevated above the ground and exposed on the top and bottom to the open air. The support of the filter media consists of iron pipes resting upon beams and girders of various sizes and formations, and these, in turn, upon columns, transferring the weight to the foundations in the ground. On this pipe floor is laid broken slag in three layers 8 inches deep, graded in sizes from 2 inches at bottom to $\frac{3}{4}$ inch at the top. Upon this broken slag, to a depth of 20 inches, is placed fine river or bar sand.

The sewage, or impure liquid, now 3,000,000 to 3,500,000 gallons per day, is brought on to upper filter beds from the pumping main, which extends along the central division of the compartments, with three lines of 8-inch galvanized iron lateral pipes controlled by valves. Each line of the laterals has twelve rows of open gutter distributors, each 3 inches deep and 6 inches wide and 3 feet in length, whose surface is about 1 foot above the water level of the filters below them. The beneficent action of light and air is here secured. The water, passing in thin films from these distributors, in its descent falls upon slatted floors, which break up the body of water into spray and small globules, getting by this means thoroughly aërated and prepared for the further purification which is to follow. Over the upper beds is a platform in the center for access to the valves and beds. It is supported on the pumping main. The beds are surrounded by 6 feet wide platforms for workmen and inspection.

The splash plates or slatted floor over the sand serves the purpose of keeping the sand from being blown away when a bed is not in operation, and also allowing it to float so as to be upon the surface of the water and prevent the wind from forming waves, which might be detrimental in any large system of water or sewage purification. As the slatted floors are in sections, they are usually removed after the

water has been cut off a compartment, and the surface of the filter beds, being exposed to the action of air and light, soon becomes thoroughly dry when the gelatinous deposit and sediment upon them, together with $\frac{1}{8}$ to $\frac{1}{4}$ inch of sand, is removed and is placed on sand pile for subsequent cleansing and re-using on beds. Some of the deposit has been used as a fertilizer. Fresh sand is employed to replace the small quantity that has been removed. The body of the beds do not require cleaning or renewal at any time, and seldom require spading or forking.

Usually there is a head of water over the top of the upper filter of about 1 foot in depth, and this, without the aid of any chemicals or pressure other than its own weight, passes through the filtering media. On the surface of the bed is formed a gelatinous product which arrests or stops all matter in suspension. The open elevated filter beds compel the air to be constant in its pressure, both above and below them, thereby ensuring an abundant circulation of air through the beds, and enabling the hardy scavenger organisms to keep in a healthy state of action. They reduce or convert all animal and vegetable matter of a malignant nature into harmless substances, thereby removing all disease-producing organic and inorganic matter.

The water leaving the lower surface of the upper filter passes in drops like rain through the open air a distance of 10 feet, and strikes upon the surface of the lower bed, causing the water to splash and rebound similar to rain upon a roof or pavement. The water, in its descent, is thoroughly aërated, while all gases are expelled into the atmosphere, and should there be organic matter in the globules, it would be burned up or oxidized by its contact with the oxygen of the air.

The water collected on lower bed, dropped there from upper beds, is usually 6 inches to 12 inches in depth. It passes by gravity through the lower filter bed without the addition of chemicals. The beds are supplied with air, having proper inlets and outlets for its circulation, and the gutters are a conduit for both water and air.

[*To be concluded.*]

REPORT OF THE CHAIRMAN OF THE LIBRARY COMMITTEE TO THE FRANKLIN INSTITUTE, MEETING OF JUNE 21, 1899.

The library is one of the most important, most efficient means the institute has for promoting applied science of all kinds. It is highly desirable that the members of the Institute should be kept well informed of the condition of the library and its progress and needs.

The library now contains about 49,600 volumes, besides about 33,500 pamphlets. It receives regularly about 460 periodicals. It is applied to by about 150 visitors a day, of whom about fifty are not members of the Institute, and are chiefly investigators of patents. In addition to applications for reference to books at the library, there are constantly about 175 volumes loaned out to members. For the increase of the library there are: The Bloomfield Moore Fund, yielding about $750 a year; the Matthew Carey Lea Fund, for chemical and physical books, about $150 a year; the Memorial Library Fund, about $50 a year, and the Jas. T. Morris Fund, lately provided by the liberality of Mr. John T. Morris, and soon to be availed of, about $50 a year; making in all about $1,000 a year for the purchase of books. The Board of Managers has appropriated this year $1,500 for the maintenance of the library, of which $500 is more particularly for binding.

The additions to the library during the past two months were 1,223 volumes, besides 584 duplicates, of which about 700 were gifts, including one very handsome gift of about 600 volumes from Dr. Wahl, Secretary of the Institute, and fifty-two volumes and twenty-seven pamphlets were purchased. There are, besides, the weekly, monthly or quarterly parts of periodicals received in exchange for the *Journal* or subscribed for. The binding of the periodicals and other volumes, which had latterly fallen seriously behind, is now gradually getting brought up again. Last year, highly appreciated subscriptions for that purpose were obtained to the amount of about $1,000, and this year the $500 from the Board of Managers will continue the work and enable the current periodical volumes to be bound. If the Board should be able to make an equal appropriation next year, the binding will be fairly well accomplished. Two new regulations have lately been established. For the benefit particularly of those who are studying up special subjects, the number of books that may be borrowed from the library by a member at one time has been increased to four, instead of two. The new additions to the library are now placed on view for a month.

The most pressing present need of the library is a suitable place for the immensely valuable, but, in its present condition, useless, collection of 33,500 pamphlets. There is no room for them in the new fireproof bookstack, and they lie in some confusion in the third story. There are two or three projects under consideration for their accommodation. The most promising, perhaps, is the construction of a fireproof room above the present bookstack; but that would cost several hundred dollars, a great sum for our slender means.

BENJ. SMITH LYMAN,
Chairman.

PHILADELPHIA, June 21, 1899.

JOURNAL

OF THE

FRANKLIN INSTITUTE

OF THE STATE OF PENNSYLVANIA,

FOR THE PROMOTION OF THE MECHANIC ARTS.

VOL. CXLVIII, No. 4. 74TH YEAR. OCTOBER, 1899

ELECTRICAL SECTION.

Stated Meeting, Tuesday, Dec. 13, 1898.

THE KITE AS AN INSTRUMENT OF METEOROLOGICAL RESEARCH.

BY PROF. CHAS. F. MARVIN,
U. S. Weather Bureau.

There is, I think, a peculiar coincidence in addressing the members of the Franklin Institute this evening upon the subject of kites, inasmuch as our beloved Franklin himself was the first to demonstrate in this very city the usefulness of kites in resolving the mysteries of the upper air.

The century and a half that has now almost passed since the famous Philadelphia experiments were made has not added all we could desire to our knowledge of kites, but I trust my remarks may, in a very small measure, commemorate the same name so grandly perpetuated in the splendid work of the Franklin Institute.

I have just said that Franklin was the first to demonstrate the usefulness of kites, but this is not exactly the

case, because we now know that two or three years prior to Franklin's sublime analysis of the thunderbolt, Dr. Alexander Wilson, of Scotland, flew kites with thermometers attached, in order to ascertain the temperature of the upper air. However, these experiments of Wilson's were not described and published until many years afterwards, and his work is justly overshadowed, both by the remarkable revelation in Franklin's discovery, and by the energy he displayed in bringing it to the attention of the scientists of his time. The electrical kite immediately became the rage, so to speak, all over Europe, but attention was directed very largely to the electrical effects, and very little to the kite itself. A notable exception of this indifference respecting the kite is found in a remarkable mathematical paper by Euler, eldest son of the famous mathematician of that name. Stimulated by the scientific use of the kite made by Franklin and many others, Euler worked out an exhaustive and elaborate mathematical analysis of the behavior of the kite.

This interesting paper was published in the "Memoirs of the Berlin Academy for 1756," but since then it seems to have been very nearly lost sight of and forgotten, and is now scarcely known. Its present interest, moreover, is chiefly historical, from the fact that the whole mathematical structure rests upon certain assumed conditions of flight that differ so widely from actual conditions that the final deductions are of little practical value. For example, it is assumed that the pressure of the wind upon the kite varies as the square of the sine of the angle of incidence. Also, that the action line of the resultant of this pressure passes always through the center of figure of the surface. Such assumptions are now known to be untenable. Euler assumed, furthermore, that the kite and the string were, together, a rigid structure; consequently, when the kite rises and falls the motion would be simply the turning of this rigid body about the fixed end of the string at the ground as a pivot. In taking the weight of the string into account, Euler neglects its curvature, but this is done in a manner that virtually affirms that the string is a rigid, heavy line. In other words, the resulting equations are such as would apply if

the kite were flown with a slender, rigid rod instead of a flexible string. Final deductions, resting upon such assumptions, have little practical significance.

Since Franklin's time a careful search shows that kites have been repeatedly recognized and, from time to time, employed as a useful piece of aërial apparatus. The first notable meteorological observations made with kites are doubtless those carried out by Archibald, in England, from 1883 to 1885. The object of these experiments was to ascertain the rate of increase of wind velocity as we pass upward from the earth's surface. This was determined on many different occasions, and, with much care, by means of anemometers carried aloft by kites.

Coming to still more recent times, it may be said that two causes have contributed very largely to greatly increase the use of the kite in aërial research. The first, and probably the more important of these, is the invention, within the past ten years or so, of greatly improved types of kites. The second cause is found in the development and manufacture of very light forms of automatic meteorological instruments. These latter enable us to measure and record at the kite the several meteorological conditions of air in which it floats, a thing which could scarcely be done, even in Archibald's time, that is, only ten to fifteen years ago.

Mr. Wm. Eddy, of Bayonne, N. J., deserves great credit for his work in perfecting a form of tailless kite. This is now generally known throughout the United States as the "Eddy" kite, and is doubtless familiar to many of my hearers.

Almost a revolution has been effected in kite-flying by the invention of the so-called cellular or box kites. This invention dates back to 1893, and is due to Mr. Lawrence Hargrave, of New South Wales, Australia. A description of these kites was read at the International Conference on Aërial Navigation, held at Chicago, at the World's Fair. Fully two years elapsed, however, before this remarkable innovation in kite construction received the attention in this country that it deserved. In the meantime Hargrave himself was busy at work perfecting and building large

size models, and actually hoisted himself into the air to a height of 40 feet with a string of his kites. The description of these remarkable experiments, published in the *American Engineer* for April, 1895, seems to have drawn the attention of kite-fliers in the United States to this type, which, I think I may safely say, is now superseding all other forms for meteorological work.

The exploration of the upper air is a subject upon which the Weather Bureau has expended a great deal of effort ever since its organization. Long series of observations have been maintained on lofty mountain summits; large numbers of balloon ascensions have been made under its auspices, and, finally, meteorological kites have been called into requisition, all with the same object in view, namely, to find out more exactly what is going on in the upper air. Observations upon mountain tops give one kind of information. Another class of data is obtained from balloons as they ascend and descend through the air currents in which they float. Finally, kites enable us to obtain still a third class of very valuable data. From my experience with the subject, I am satisfied that kites can, and I believe they will, be perfected very much beyond their present state, and in that case they will, no doubt, in the future, find a permanent place among the instrumental equipment of meteorological observatories.

In the fall of 1895, Prof. Willis L. Moore, the Chief of the Weather Bureau, decided to undertake investigations for the purpose of ascertaining to what extent the kite equipped with self-recording instruments is available in making *daily* soundings of the atmosphere to a height of a mile or more. It was then well known at the Bureau that the mere addition to the kites of a small load in the shape of recording instruments involved no new difficulty in securing an ascension. This had been repeatedly demonstrated in the preceding 150 years. The real problem was to produce thoroughly trustworthy kites that would, themselves, reach great elevations, and do this *daily*, if possible, and without frequent mishap and loss. It has been my pleasure to have charge of this work during the past three years.

At first the work was purely experimental, during which stage many important improvements were effected in the design and construction of kites; a sound mechanical basis was formulated to explain the action of the forces due to the wind and string, and methods were established by which to measure and express the efficiency of kites. This period was followed by one devoted to inventing and perfecting appliances embodying the results of previous experiments and which were adapted to be issued to stations and used in making daily ascensions.

Finally, coming down to the present year, sixteen of the regular stations of the Weather Bureau, in addition to one at Washington, were equipped with complete kite-flying outfits, each in charge of a special observer who received at Washington a preliminary training in the art and practice of flying kites.

This undertaking on the part of the Weather Bureau is a notable step forward in meteorological research. The very limited funds available, however, has confined the work, thus far, to a mere preliminary survey, and during the present month it has been necessary to suspend operations at all but two or three of our aërial stations. Nevertheless, enough has been brought out in what has been done to demonstrate the cheapness and availability of this means of aërial exploration, and plans are now maturing for marked improvements in both the kites and the meteorological instruments.

The United States, represented by its official corps of Weather Bureau kite observers, under Professor Moore, and ably supported by the splendid independent achievements in kite building and flying of such experts as Ferguson, Clayton, Eddy, Wise, Lamson, Woglom and many others, has undoubtedly taken the lead in perfecting kites and employing them in aërial researches, but a great many workers on the problem are now in the field all over the world, and we may reasonably expect very great improvements in kite-flying in the near future.

I have attempted to give in the foregoing a very brief historical sketch of the use of the kite in aërial research,

but I realize how imperfect it is, and that it has been impossible to include many essential points without extending this portion of my remarks to too great length.

THE WEATHER BUREAU APPARATUS.

In designing the apparatus employed at the Weather Bureau stations it was necessary to adopt such forms and types as could be used everywhere alike and by persons having no previous experience either in kite-flying or even in general meteorological work. Fifteen of the seventeen aërial observers had never taken part in flying kites for scientific work at the time they reported at Washington for two weeks' instruction in the work, before taking charge of their several stations. Only four of the men had had previous experience in conducting the regular meteorological work of our stations. The new men were drawn from the lists of eligibles who had passed the civil service examinations for Weather Bureau observers.

Taking this inexperience into consideration, and the comparatively untried and unperfected nature of the whole mechanical apparatus employed, the very satisfactory results of the first six months' work testify both to the general correctness of judgment displayed in the choice of the appliances and to the entire practicability of using kites in such investigations.

Kites were broken from time to time, and from 10 to 20 per cent. of the entire supply of steel wire employed in flying the kites was lost or rendered unserviceable by entanglement, etc., but not a single one of the registering instruments sent up with the kites was lost or even seriously injured. This gratifying result is attributed very largely to the practice uniformly adopted in the Weather Bureau work of suspending the meteorograph within the framework of the kite. Even if the latter breaks away, its fall through the air is slow, and the nature of the structure is such as to completely protect the instrument from any severe shock or injury when the kite strikes the earth or other objects in its descent. Those who advocate flying several small kites in tandem, as compared to one large kite, are compelled to sus-

pend the meteorograph at some point on the main line below the kites, where their combined action is effective in supporting it. The instrument in such a position is exposed to much greater danger of loss and injury than within a kite large enough to fly efficiently in spite of the increased weight. The superior efficiency of one large kite over several small ones was fully demonstrated in our early experiments,* and, in proportion to the length of line used, the supporting surface spread to the wind, the weight of instru-

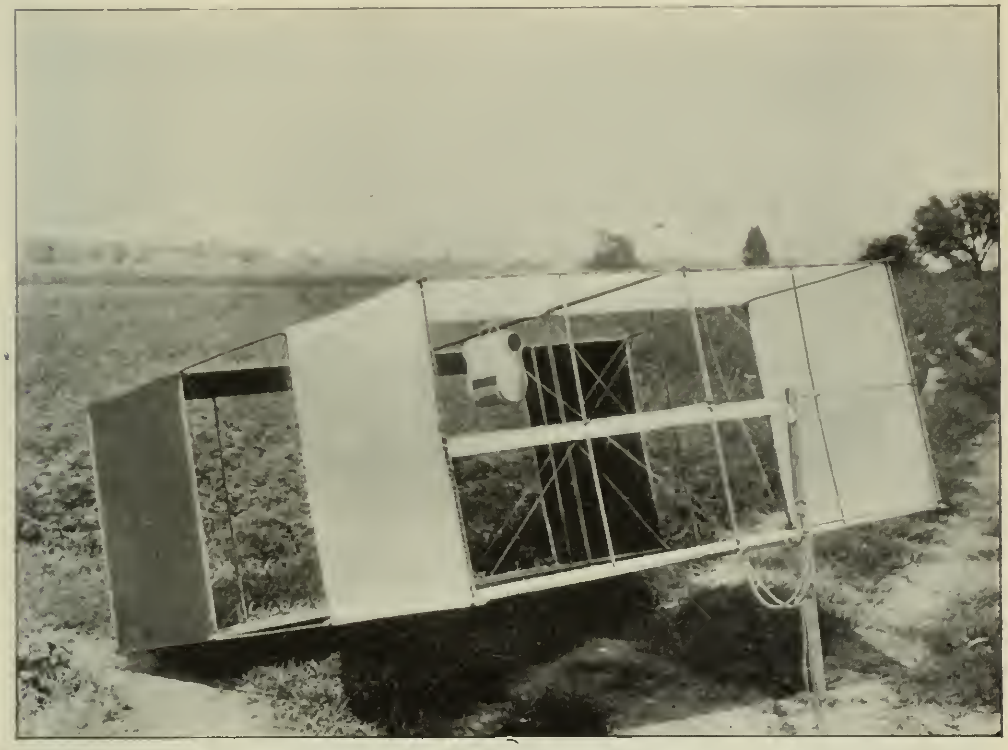


FIG. 1.—Weather Bureau kite and meteorograph.

ment carried and the tension on the line, the elevations reached by the standard kites of the Weather Bureau show them to be much more efficient than any whose records of efficiency have, thus far, come to our notice.

Standard Weather Bureau Kite.—I am fortunate in being able to exhibit this evening this large kite (*Fig. 1*) before you, which was built and kindly placed here for my use by

* Kite experiments at the Weather Bureau. *Monthly Weather Review*, Vol. XXIV, p. 253.

Mr. Charles Day, of Germantown, Pa. It represents, in all essential respects, the medium-size Weather Bureau kite; the only differences are in the structural details. The supporting surface of this kite measures 68 square feet. A smaller kite, with about 45 square feet of supporting surface, and a slightly larger one than this, with 74 square feet of surface, have also been employed. In order to permit of easy transportation to stations, the kite readily admits of being collapsed to the shape shown in *Fig. 2*. The general plan of

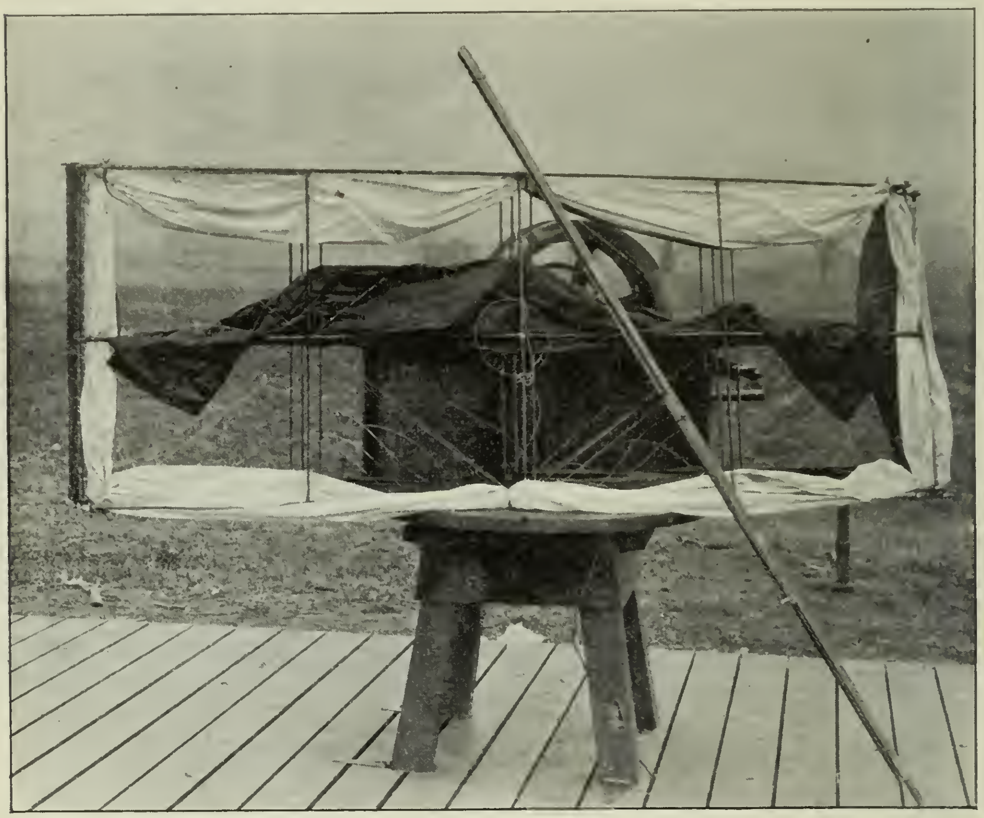


FIG. 2.—Kite collapsed.

construction is gathered from this figure. Four rectangular frames, 78 inches by 32 inches, are formed of straight-grained spruce strips, $\frac{5}{8}$ inch by $\frac{1}{4}$ inch, cross-section, rounded edges. Each frame is braced by transverse struts and further made rigid by four exactly equal ties of tempered steel wire. These are stretched slightly taut from each corner of the frame to the top and bottom ends of the middle brace. All points of junction of the sticks of the frame are formed by

the aid of light sheet-tin angle pieces, punched out under dies in a form to fit the wood exactly, and at the same time give the maximum stiffness to the thin sheet metal. The tins and the wood are all lashed firmly together by No. 16 gilling thread, thoroughly coated with soft shoemakers' wax. The angle tins are formed with a view to providing a secure point of attachment for the ties, the wire of which is twisted up at each end to form an eye large enough to admit a wire nail about $\frac{1}{16}$ of an inch in diameter. The steel wire has a tensile strength exceeding 200 pounds, and the tins, as shown by tests, afford an unyielding point of attachment of equal strength. Similar tie wires contributing rigidity to the kite in the longitudinal sense, though slack, are not detached when the kite is collapsed, but come taut when the longitudinal spines are put in place. This is accomplished in a few minutes by the aid of small machine screw bolts, which pass through the longitudinal spines and clamp them to parts of the angle tins employed in joining the members of the rectangular frames. The cross-section of the corner spines is $\frac{1}{4}$ inch by $\frac{5}{8}$ inch; that of the central top and bottom spines is $\frac{1}{2}$ inch by $\frac{5}{8}$ inch. The cloth bands are 24 inches wide, and the distance between cells has varied from 24 to 30 inches. Excellent results have been obtained with a distance of 28 inches between cells. The cloth is prepared in strips of sufficient length; the edges and ends are hemmed with a cord inserted. The strip is then placed around the frame of the kite and the ends sewn together; the edges all around being also sewn to the sticks of the rectangular frames. The white cloth in the front cell is Lonsdale cambric, which is of very close weave and is stronger than the black percaline chosen for the rear cell on account of its color, in order to increase the visibility of the kite.

According to the theory of the kite, fully confirmed by practice, the principal function of the rear cell is simply to preserve equilibrium between the forces due to the wind, the string and gravity, and, except when the wind is very light, the pressure per unit area on the forward cell is many times that upon the rear cell. Under these circumstances, the correct procedure in order to secure greater lifting

power per unit weight for the whole kite is to increase relatively the proportion of surface in the forward cell, which explains why the front cell, in the Weather Bureau kite, is provided with three supporting surfaces while the rear cell has but two.

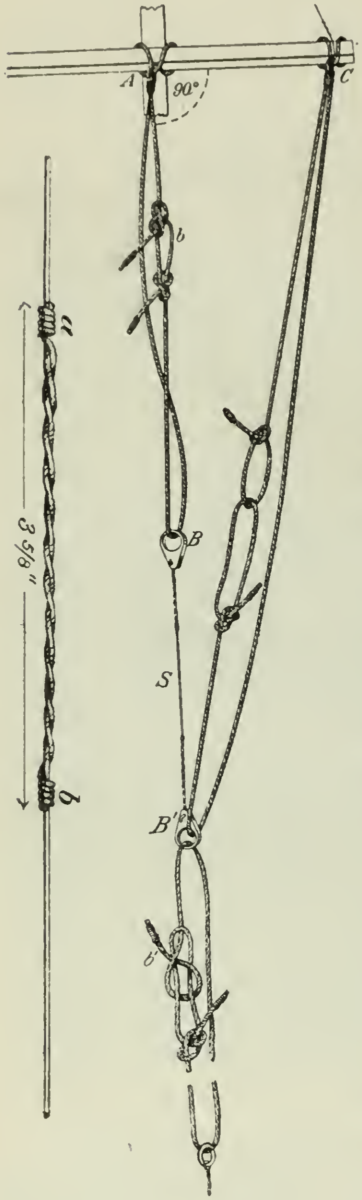


FIG. 3.—Bridle and splice.

The Bridle.—Whatever connection in the nature of a string or cord is employed to join the main line to the kite frame may be designated by the term bridle, the exact arrangement of which varies greatly in different kites. Mechanical considerations show that certain advantages arise when the kite is so bridled that the point of attachment of the main line to the frame is well forward (the forward end of a kite is the end the wind first encounters as it flows over the structure in normal flight). Under these circumstances the kite tends, in a greater degree than otherwise, to "spill the wind" from the sails, under strong gusts, and, with this end in view, the Weather Bureau kites are bridled at a single point, namely, the middle point of the foremost lower edge of the front cell. The presence of three, instead of two, supporting planes in the front cell improves the action of the kite when bridled in this manner. Notwithstanding the advantages realized in this bridle, the pull of the kite in the very strongest winds will increase to a dangerous point, and another device, called a safety line, has been employed, in order to prevent the breaking of the main line or the kite when the strain becomes dangerous. The standard kite and line are safe, as a rule, when under a

strain of from 85 to 100 pounds, and generally withstand considerably greater strains. However, the safety line is chosen from fine, tempered steel wire having a tensile strength of about 85 pounds. A short piece of this is inserted between the main line and the kite, as shown at *S* in *Fig. 3*, and carries all the strain, which, on exceeding 85 pounds, will necessarily break the safety line; whereupon another connecting line, previously idle and a little slack, immediately comes up taut, and the kite thereafter flies from a new point of attachment, *C*, several inches in advance of the normal point; all of which has the effect of reducing the strain on the kite under the same wind force.

It is often suggested that in place of the safety line, *S*, an elastic cord or spring be used, which, stretching with increased strain, transfers the equivalent point of attachment from *A* towards *C*. If the mechanics of this arrangement be analyzed, it will be readily seen that to be effective the point *C* must be carried very much further forward than otherwise required. It is claimed by some who have advocated the use of this device that it limits the strain on the line in gales of wind. It is easy to demonstrate the fallacy of this simply by the parallelogram of forces; in fact, it is obvious that the elastic connector will not stretch more and more as required, except as it is subjected to greater and greater strains; but this is not the only difficulty, for, as the elastic stretches a little, a part of the strain is carried to the point *C*, and the total strain that must be carried by the line and kite increases at a greater rate than the part of it which tends to stretch the elastic connection, thus nullifying the advantage claimed. On the other hand, the safety line, in spite of certain obvious defects and objections, possesses highly valuable features.

The Line and Reel.—Steel music wire is the best material for kite lines, on account of its great strength in proportion to weight, and especially on account of its slender cross-section; the pressure of the wind upon the line being a very important detrimental factor in limiting the elevation of ascensions. The wire used in the Weather Bureau work

has a tensile strength of over 200 pounds, and measures ·028 of an inch in diameter. It can be drawn in lengths of 7,000 feet or thereabouts, if necessary, so that but few splices are required. Where splices are needed, these are made by twisting the wires together in the manner shown in *Fig. 3*, the joint being thoroughly soft-soldered at a low heat.

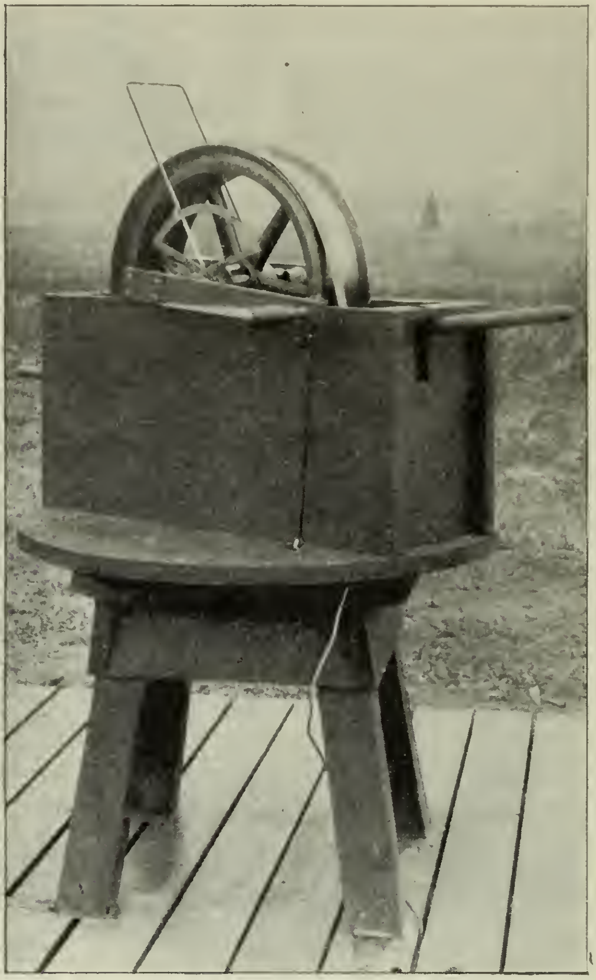


FIG. 4.—Hand reel.

The station at Washington is equipped with an automatic steam windlass, but a very conveniently mounted hand reel, as shown in *Fig. 4*, was issued to stations. The iron drum is cast in one piece, the metal in the rim being about $\frac{5}{8}$ of an inch thick under the wire. The rim can safely resist a crushing force exceeding 200,000 pounds.

This enormous strength, as is well known, is necessary to withstand the cumulative effect of winding on a great many turns of wire under strong tension. A single turn of wire around the drum, under a uniform tension of 50 pounds, for example, subjects every transverse section of the rim to a compressive force of 50 pounds. The next turn at the same tension adds 50 pounds to the preceding pressure, and so on. Two thousand turns at this rate will, therefore, produce a crushing pressure of 500 tons. In actual practice, the crushing pressure is not quite so great as this, because the wire yields a little as the pressure increases, and this lessens the tension of some of the turns of wire already in place on the drum. The crowding of the wire laterally tends also to burst off the side flanges, and, to obviate this, it is best to wind the wire on in a regular crisscross fashion, which both lessens the lateral crowding and also prevents the wire passing onto the reel from squeezing through and entangling with what is already wound on.

The circumference of the drum is about 5 feet, and suitable dials, moved by a worm on the axis of the drum, indicate the number of turns of wire paid out. The length of wire is deduced from the dial reading, due allowance being made for the change in the circumference as more and more wire is wound on or off.

The unwinding of the drum is controlled with great ease by a strap-iron friction brake working on a flange of the drum and operated by the lever seen at the right in the picture. The reel box turns in azimuth on the table beneath, and can thus be adjusted to the kite in any direction of flight.

The tension on the wire is shown by an index and scale attached to one of the crank handles. A hook on the reel box can be readily engaged in a spring on the end of this crank handle, and serves the double purpose of locking the reel against further unwinding, and the position of the index shows the strain on the wire at all times. The crank handles are made of wood, thoroughly shellacked, in order to electrically insulate the operator from the metal reel and wire, which are generally electrified during ascen-

sions. The metal parts are, however, all connected to "earth" by means of a wire and iron rod driven into the ground a few feet. A small switch in this circuit enables the operator to judge of the extent and nature of the electrification by means of the sparks which jump over a gap in the circuit.

The slender, bent, aluminum radial arms, together with the graduated arc of a circle, seen in the picture, constitute an arrangement for measuring the inclination of the wire line to the horizontal. The arc is supported on two small

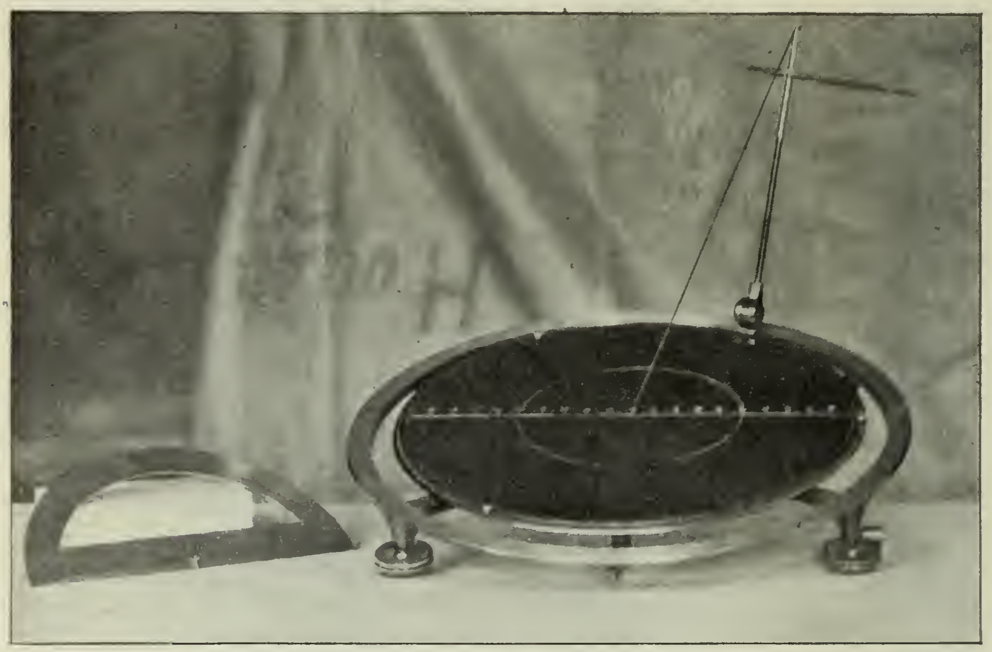


FIG. 5.—Nephoscope (Marvin).

wheels which run in a groove on the shaft, the correct position of the arc being assured by a weighted rod pendent below the center of support. The several parts of the reel may be detached with complete facility. The cranks and radius rod, when not in use, are stowed inside the box, which is then covered and locked. The wire is sufficiently protected from the weather by keeping it thoroughly coated with vaseline applied by a brush from time to time to the wire on the reel.

Ordinary Conditions of Flight.—In a favorable wind of from 15 to 20 miles per hour at the surface, the kite will fre-

quently fly at an angular elevation of a little over 50° with about 5,000 feet of wire out. In the highest ascensions yet reached with a single kite, namely, from 8,000 to 8,500 feet, vertical elevation, the angular elevation has ranged from 30° to over 40°, and the length of line employed from 11,000 to 13,000 feet. The pull has ranged under these circumstances from 50 to 80 pounds.

The elevation of the kite is determined from the measured angular elevation of the kite and the known length of line out. A correction is made for the sag of the wire, which is shown by the difference between the angular elevation of the kite and the inclination of the wire at the reel. These two angles are the same if there is no sag. The correction varies from a few tenths of a per cent. to over 2 per cent. of the total length, and is computed from the equations of the catenary on the basis that the curve assumed by the kite line is a simple catenary. This neglects the effects of the lateral pressure of the wind on the wire, which is very appreciable, and no doubt modifies the curvature of the wire considerably. The error of the computed percentage of sag on this account is, however, of slight importance.

The angular elevation of the kite is determined by means of a nephoscope,* an instrument ordinarily employed for measuring the angular position of clouds and their apparent motions. The instrument is shown in *Fig. 5*, and consists, essentially, of a mirror mounted on levelling screws, with an adjustable sighting staff. A fine thread fastened to the topmost point of the sighting staff passes through a fine hole in the center of the mirror and is kept taut by means of a small plummet below. To make an observation, the image of the kite in the mirror is brought to the central point and the sighting staff adjusted until the image of the knob coincides with that of the kite. The angle between the thread and the mirror, that is, the angular elevation of the kite, is then measured by means of a protractor, graduated to half degrees. The accuracy attainable with this apparatus suffices for all ordinary ascensions

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* *Monthly Weather Review*, U. S. Weather Bureau, Vol XXIV, 1896, p. 10.

where the movement of the kite itself prevents the most exact measurements. In high ascensions a theodolite or sextant is required, and both have been largely used in the work at Washington.

The Meteorograph.—Manufacturers of meteorological instruments have not yet put on the market any good form of kite meteorograph, that is, an apparatus light enough to be

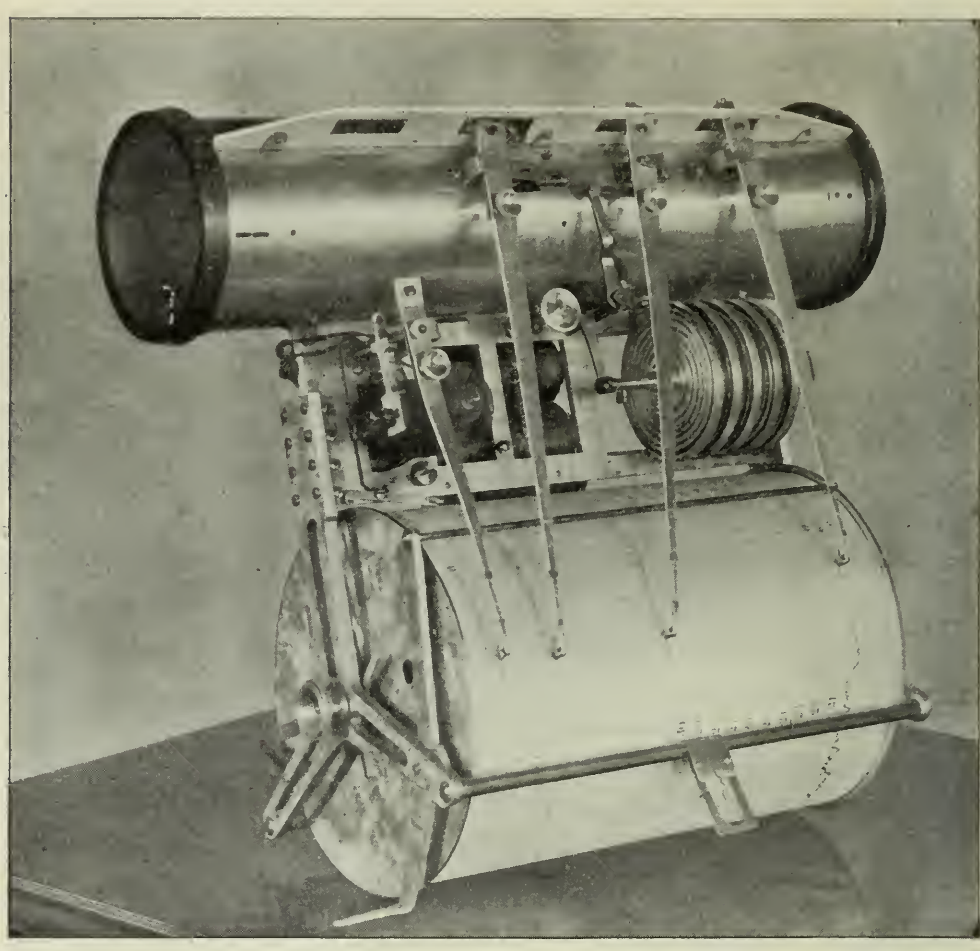

FIG. 6.—Marvin meteorograph.

carried aloft by kites and adapted to automatically record the desired meteorological elements. The meteorograph shown in *Fig. 6* and employed in the Weather Bureau work was constructed by a New York manufacturer, in accordance with designs and specifications furnished by the Bureau. The instrument records four meteorological elements on the same sheet of paper, which is wound around a

suitable cylinder moved by clock-work inside. Ordinarily the speed of rotation of the cylinder is one revolution in twelve hours; that is, one inch on the sheet per hour; but, for testing purposes, the simple tightening of a nut enables one to change the speed to one revolution per hour.

The pen at the extreme left in the picture records the wind movement by means of a small anemometer attached to the kite. Thus far, the anemometer has been used only on the kites at Washington.

The next pen in order records the temperature of the air; the third pen the pressure of the air, and finally, the pen on the right side of the picture records the percentage of moisture in the air.

When the instrument is attached to the kite, the wind blows with full velocity through the long tube seen at the top of the picture, thereby causing the thermometer bulb and hair hygrometer exposed therein to take on as perfectly as possible all the successive atmospheric conditions. Not only does this arrangement secure the most satisfactory ventilation for the thermometer and hygrometer, but it also completely screens them from direct sunshine. Hard-rubber rings at the ends of the tube, and strips of ivory extending lengthwise, prevent any direct metallic contact between the long tube and the outside case of the instrument, thus cutting off any heating of the thermometer by the action of sunshine on the case.

The thermometer bulb consists of a pair of Bourdon tubes filled with alcohol. The tube is ellipse-shaped, in cross-section, but very sharp at the ends of the long diameter. The major and minor axes of this ellipse are about $\frac{9}{16}$ and $\frac{1}{16}$ of an inch, respectively. The thickness of the metal is only about nine thousandths of an inch. These tubes, closed at each end, are formed into nearly a complete ring $1\frac{1}{2}$ inches in diameter, and completely filled with alcohol, so as to perfectly exclude all the air. The short gap between the ends of the tube is opened beyond its natural width by a wedge, or otherwise, while the alcohol is being introduced, and the tube is then hermetically sealed by soldering. By this procedure a state of internal stress is set

up in the tube, when the wedge is removed, and the ends, by the elastic action of the metal, tend constantly to approach each other, but are prevented from doing so by the alcohol, except as it contracts in cooling, or spreads the ends still further apart on expanding. This type of thermometer has been extensively employed in thermographs, but heretofore the bulbs have been made only of brass, or composition metals, the elasticity of which is so imperfect that the best results cannot be secured. The tubes in the Weather Bureau instruments were made of carefully tempered steel, the elastic reaction of which was practically perfect. Two small tubes are employed in each thermometer, instead of one larger one, in order to secure the highest practicable degree of sensitiveness. Carefully conducted tests show that under the conditions arising in practical work, that is, when the kite rises or falls rapidly through successive strata at different temperatures, the lag of the thermograph is only about 1° F., when the air temperature steadily changes at the rapid rate of 1·5° per minute. Ordinarily, this would correspond to a rise or fall of the kite of nearly 500 feet per minute. Experience has shown that the thermographs, as ordinarily constructed by manufacturers, are entirely too sluggish for satisfactory results in kite work.

The registration of pressure is effected by the well-known aneroid barometer mechanisms. The inherent errors of this type of apparatus have been extensively studied and are well known to careful investigators in these matters. Thus far, no maker has been quite successful in eliminating a considerable error due to the imperfect elastic qualities of the metal of which the vacuum chambers are constructed. Usually, brass, or similar composition metal, is employed. The aneroids in the Weather Bureau meteorograph were, however, made of steel, the more perfect elastic properties of which it was expected would contribute better action. This was shown to be true by careful tests of similar barographs of steel and brass chambers. The difficulty was not removed, however. The absolute errors are, in fact, quite small, but the study of atmospheric phenomena requires a

very accurate measurement of pressure, and errors of $\frac{1}{10}$ of 1 per cent. are of importance. Recent studies of the errors of aneroid mechanisms have indicated directions in which still further improvement is possible.

The hair hygrometer is about the only type of hygrometer that seems practically available in the construction of a kite meteorograph, but it is, nevertheless, not as sensitive and reliable as we desire. Ten minutes or more are required for the hairs to show a change of 10 per cent. in the humidity. Aside from this sluggishness, the indications of the instrument are not wholly reliable and should be frequently checked and verified by comparison with readings of the wet and dry-bulb thermometers.

The greatest need in kites for future work is a more perfect means of automatic adjustment to extremes of wind velocity and considerable reduction in weight of the structure so that better ascensions can be made in light winds. The remarks already made in respect to the errors of the recording instruments indicate the nature of improvements required therein.

Stated Meeting, Tuesday, January 24, 1899.

THE PRACTICAL APPLICATION OF ELECTRIC MOTORS TO PRINTING PRESS MACHINERY.

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The past five years have seen marked advancement in the transmission of power by electricity.

Aside from long-distance transmission and railroad work, no branch of the art can show such substantial results as have been accomplished in the field of individual motor application. In this latter the application of the electric motor to printing press machinery has produced results in power saved, improved product and increased output sufficient to cause every large printer to-day to look upon electrically-driven printing presses as a necessity and not a luxury.

Passing by the early arguments used for adopting the individual motor, the engineering problems of what is the best and how shall it be applied are now ready for consideration.

It will be necessary to subdivide the subject, considering each separately, afterwards drawing conclusions from facts submitted.

The following is the definition of "geared" and "direct" motors:

Geared are single reduction motors.

Direct have the armature of motor keyed to the main driving shaft of press.

MAIN TOPICS.

Types of motors, attachment, control, protection, maintenance, cost of operation, advantages, a few facts of the power consumption of the government printing office.

These headings are themselves subdivided.

Types of Motors.—There are three kinds of motors used in printing press work, viz.: series, shunt and compound wound.

Series Motor, owing to its speed varying directly as work done, gives an unsteady and jerky motion to press, which interferes with securing the highest grade of presswork.

Shunt Motor, while giving much better results as to constant speed at all parts of the stroke of the bed of a press, is lacking in starting torque so essential in handling a press during "make-ready," as well as starting the press from all positions of the bed.

Then if lead of brushes is altered to overcome sparking, there is a corresponding change in speed of press shaft.

This fact the pressman sooner or later will discover and more than likely take advantage of on hurried work, ex cessive sparking from a distorted field causing him but little worry.

Compound Motor gives by far the best results for printing press work, having a stiff starting torque, constant speed and minimum sparking at moment of reversal, a constant factor in this class of work.

The commercial demands are for a tough motor, one built to withstand rough handling, overloads, long strains of work, not similar to pumps or blowers, which is constant, but the continuous starting and stopping, reversing, producing conditions which can only be met by a motor mechanically and electrically rigid in all its details; one free from repairs, always ready to be pushed to its maximum.

Sizes.—Motors should always be sufficiently large to handle the presses to which they are attached without straining, and wound for highest efficiency at 70 per cent. of rated output.

For example, suppose we have a 5 horse-power motor attached to Huber press, bed 42 x 52 inches, running at 1,300 impressions per hour, printing 32 pages solid matter, using book ink and running under favorable conditions, the current consumption fluctuating from 12 to 30 ampères at 115 volts; allowing 8 ampères per horse-power, we have, for a 5 horse-power motor, 40 ampères, 70 per cent. of which is 28 ampères.

This press will take to start, varying according to position of bed, from 35 to 50 ampères at 115 volts.

From these figures it is seen that the press is handled promptly and properly, with ample margins, without using too large a motor.

These figures apply to presses that have been in operation some months, not to those newly installed, for often these will demand double the figures mentioned until they become "limbered up," during which time the motor will have a little extra work to perform, but a good motor will withstand this ordeal without harm.

In selecting the size of a motor, do not figure tóo close; get one sufficiently large to do your work without loss of time to the operator.

The price of motors is not direct as the horse-power, a 5 horse-power costing only about 15 per cent. more than a 3 horse-power motor, while you obtain 66⅔ per cent. more power.

The efficiency of a 3 horse-power and 5 horse-power

motor, both running under load of 2 horse-power, will be within 2 or 3 per cent. of each other, thus placing each on substantially the same basis as to commercial efficiency.

This reserve power will prove a valuable source of revenue before the year is closed.

Belted, Geared and Direct-Connected Motors.—The main advantages to be gained from the individual application of electric motors to printing press machinery are steadiness of power as applied to main driving shaft, absence of overhead belting, economy of floor space, increased output and ability to place presses in a room irrespective of a main line of shafting.

The main difficulty with belted motors is the slippage of the belts, which frequently causes poor register and slurring; with overhead belting this is further increased from dust, dirt and scales, which are constantly given off from the surface of the belts, battering plates, and the obstruction to light in the room all tend to decrease the output.

In fact, the belted individual motor has only two advantages over the main line driving, viz.: Location and independence of main line, in case anything happens to belting which might necessitate shut-down of all the presses.

As it retains all the disadvantages of the main line drive, it should be discarded where good work is wanted.

The geared and direct-connected motors only will hereafter be considered.

To reach a conclusion as to which is the better will, in most cases, necessitate an individual consideration, first, by the electrical engineer and the press builder, and, finally, by the proprietor, who pays the bills.

The principal features of each should be considered separately.

Geared Motor.—This must be of moderate speed, not of a high speed, for then the reductions, motor to press, are prohibitive.

Speeds should be from 1,000 revolutions per minute for 1 horse-power, to 500 or lower for 15 horse-power; this will permit of a suitable mechanical reduction and attachment to presses whose main driving shafts vary in speed from 90

to 175 revolutions per minute. When this is exceeded, it is almost impossible to make the press—one of the large types—run quietly, and if noise is an objection, the direct-connected type becomes advisable.

Hardly any two makes of presses have the same shaft speed, nor are the diameters of shafts the same; so for presses of same sized bed and production there is required for each make of press different ratios of reductions, which can be easily supplied by gearing, always using the standard motors.

While with the direct-connected motor, the armature, being keyed to press shaft, must be built especially for this individual type and make of press.

Its interchangeability with other presses of different manufacture is a great rarity.

If press is sold or replaced by another, the motor must be made over to suit, or else thrown away, while the standard geared motor is always ready for use with a change of gearing.

The ratios in presses vary from 4 to 1 to as high as 12 to 1.

Press ratio means for every 4 or 12 revolutions (as case may be) of press shaft there is made one impression.

In some cases the geared motor takes up more floor space than a direct-connected, but not always, notably in the stop-cylinder type, which has driving shaft at the rear of press, enabling motor to be placed under the delivery table, reducing the floor space even of belted presses.

Should trouble occur to the "direct" it is much more serious, for this means a shut-down of the press, until injured parts can be repaired or furnished by factory.

Waiting for special made motors to be repaired or rebuilt is very tiresome, as those of us know who have to place ourselves at the mercy of manufacturers.

Duplicate geared motor armatures can be kept on hand and change made easily during "make-ready," with no loss whatever of production.

Owing to the wide variation in speeds, bore of shafts, it is impracticable to keep on hand "direct" armatures; cost

is prohibitive to keep a special armature for each size press.

Increased cost of direct over geared is from 25 to $33\frac{1}{3}$ per cent. for new presses as they come from the factory; cost of installation about the same.

Difference in cost of electrically equipping presses already supplied with belting depends largely upon circumstances, whether shaft has to be lengthened, turned off, etc.; but cost is nearly equal if gearing has to be bought and pulleys cannot be sold.

These figures refer to motors of about 5 horse-power and speed 175 revolutions per minute and up; smaller sizes, as well as lower speeds, make material advantages in favor of geared motors.

Voltage should be either 115 or 230. Five hundred volts is too high to have about so much metal which employees are constantly touching.

Attachment.—I wish to call particular attention to this part of the subject under consideration, for it is one that the electrical engineer is more likely to slight, it being wholly mechanical engineering.

First, in every case make the motor part of the press; it must *not* be placed on a separate foundation; it is absolutely essential that this be rigidly adhered to in all cases where satisfactory results are expected, for otherwise the gearing will get out of line. In the case of "direct" motors, there is liability of the armature hitting against the pole pieces or else bind the main press shaft sufficiently to get a hot box and cut the shaft.

Next in importance is to provide a proper foundation; in most cases up to 3 horse-power, an iron bracket of sufficient strength, securely bolted to frame of press, will meet all the requirements; in all sizes from 5 horse-power and upwards, an extension of masonry foundation on which press rests should be made; cast-iron motor base must not only be bolted to press, but anchored to the masonry foundation by grouting in cement or with anchor bolts—in many cases both should be done, thereby obtaining a foundation amply massive to take care of all the jars and strains to which

the motor will be subjected, without running the risk of loosening the bolts in foundation and getting motor out of line.

In a "Huber" press, running at a speed of 1,500 impressions per hour, the bed is travelling at the rate of 300 feet per minute; weight of bed, with form, over 1,000 pounds; a total of over 300,000 foot-pounds to take care of, while the press is running at full speed within a bed travel of 4 to 5 feet, with reversal following immediately. To cause a more sudden stoppage would be disastrous to the machinery of the press.

The rough usage to which the electric motor is subjected on presswork is such that if repair bills are to be kept down, the initial cost must not be the sole guide.

In the case of direct motors, the outboard rigging makes it much easier, at the same time presenting a more graceful appearance when finished, to attach motor to press without either foundation or motor sub-base. In this case the supporting brackets must be rigid and bolted to press with a "driving fit," for, when play is left in bolt holes, trouble is sure to arise sooner or later from the motor shifting its position.

Even with direct-connected motors, it is best, wherever possible, to provide a sub-base, for reasons mentioned in connection with geared motors, as well as the assistance received during installation. The proper handling of motors weighing from 500 to 1,100 pounds, while working to a "driving fit," with the ordinary appliances at hand in a printing office, is not rapid or satisfactory work.

Gearing should consist of rawhide pinions with cast-iron gear wheels, being sure to have both pinions and gear wheels cut by the same factory. Having rawhide manufacturers cut the pinions, and press builders or some other machine shop cut the gear wheels, invariably results in noisy running gears. Engineer should give personal attention to this when installing work.

The gear wheels should be fitted with taper bore, keyway and cap on end of shaft. The use of set screws is not satisfactory.

The pinion should be of the best grade rawhide, having brass sides and sleeve, latter thicker than depth of keyway. Face wide enough to allow for armature vibration, without metal sides running on face of gear wheel.

Teeth should not be too fine pitch. My experience has been that, for ordinary work, a 4-pitch diameter tooth is thoroughly satisfactory, showing little wear after continuous use for several years.

On heavy presses it is advantageous to connect, by means of a stiff wrought-iron bar, the press and motor bearings.

Satisfactory ratios of reduction, motor to press, from 10 to 1, desired speed not exceeding 120 revolutions per minute; 5 or 3 to 1 on higher speeds. These will run well, and with little noise or wear, for several years.

Great care must be exercised in selecting the workmen that are intrusted with the lining of the gears; this is one of the most important parts of the installation of the electrical equipment, and should be intrusted only to trained experts in this class of work.

Position of Controller.—In attaching the controller to the press, care and judgment should be exercised to place same so that the handle is convenient to the press feeder, the direction being away from the body while starting press and towards the body to stop, which at times must be done immediately to prevent sheets getting on the roller, etc.

This should be fastened to a cast-iron bracket, when possible; otherwise, wrought-iron supports well braced will answer.

Wiring demands high-grade insulated wire, so protected that it cannot meet with mechanical injury.

The hanging of wires from the ceiling should not be permitted, as it is not safe, at same time interfering with the proper handling of the press.

On most presses the feeder is on the opposite side of the press from the motor, therefore, wires must be run across press to same. About a press is much oil and ink, all detrimental to the insulation of the wire, which must be kept perfect to insure uninterrupted use of the press. This can be secured by using highest grade rubber wire, taped and

braided, enclosed in a continuous length of flexible tubing, these finally encased in black iron pipe, said pipe to be firmly bolted to press, if running across, or cemented into foundation with painted joints if running underneath press. If this method is adhered to, the thought of ever having trouble from your wiring may be placed to one side.

Personal experience has shown that, where this method has been followed, we have never had a leak on our wires.

The knowledge that wiring when once installed is perfect and will give no trouble is fully appreciated by the engineer in charge, and will be by the proprietor, after a few *expert* bills for testing wires have been paid.

Keep controllers and rheostats as far away from the floor as possible; they will be kept cleaner and are less liable to damage from scrubwomen and trucks than if placed on the ground.

Control is a subject to which more care and thought has been devoted by electrical engineers than all the rest of the equipment combined.

A casual glance at what is necessary to properly handle a printing press before starting to print will disclose the problems which had to be solved. Take a large flat-bed two-revolution press, bed 42 x 52 inches, or one large enough to print 32 pages 16mo at an impression, as an example. Starting from the "make-ready," when the pressman places the form on the press and begins to see what is necessary to produce good work. In placing "overlays" on the cylinder, the press is moved a few inches forward, then reversed, or the cylinder is turned ahead a half revolution, then reversed a quarter, etc. In placing plates on the press, many times the bed is needed to be moved not over an inch or so; all this must be done quickly and absolutely, for unless the press is under perfect control an accident may easily occur. The more perfect the control, the less time is the press idle and becomes a wage-earner instead of an interest-eater.

After the press has been started and working satisfactorily, absolute control must continue, as there will be occasion to stop same quickly within stroke of bed or even less;

this must be while under full speed and in such a manner as not to jar or injure the press.

Speed Control.—There are several methods in vogue at the present time, viz.: Resistance in series with armature, commutated field, field control by insertion of resistance, combination of resistance in armature and resistance in series with field, having the former take care of about two-thirds range of speed, then depend on weakening the field for the balance.

The latter method gives the widest range of speeds and for direct motors is the most satisfactory to install, both to seller and purchaser.

Most every engineer, without exception, cries down the armature-resistance method as grossly extravagant. On the surface, or from a theoretical standpoint of the motor itself, this is correct, but what are the facts in actual practice?

In most large offices certain presses are used on work which requires nearly always the same rate of speed, although the character of the work may not be uniform. These presses can be fitted with gearing suitable to give proper speed when motor is "full on," using the resistance only as a starting medium, rather than a speed regulator.

To convince myself what the actual difference was in commercial work, I conducted experiments and tests, lasting over six months, taking geared motors with armature control, and "direct" having commutated field.

Method of test was as follows: To each press was attached a "Thomson Recording Wattmeter," carefully calibrated. Readings were taken daily. The output was taken from the daily report of pressman to foreman of the press-room.

These were all attached to same size and make of press, doing regular bookwork. From day to day there were some striking differences, yet at the end of each month and the close of the six months' test the armature control held its own, showing an efficiency not usually accorded to it.

The following is the test in detail:

OUTPUT AND POWER CONSUMPTION, HUBER PRINTING PRESSES (BED, 42 x 52). JULY TO DECEMBER, 1897. GOVERNMENT PRINTING OFFICE.

No. of Press.	Watt Hours Consumed.	Work Done, Impressions.	Watt Hours per Impression.	Type of Motor.	Method of Control.
4	1,055,400	788,843	1·337	Direct.	Commutated field, compound.
5	832,700	572,991	1·453	"	Resistance in field, shunt.
6	1,152,800	766,512	1·503	"	Commutated field, compound.
7	861,200	436,552	1·972	"	"
8	998,800	525,010	1·902	"	"
9 . . .	777,600	487,306	1·595	"	"
10	1,265,700	729,986	1·733	"	"
11	1,274,000	754,884	1·687	"	"
12	931,300	563,731	1·652	"	Commutated field, series.
13	1,250,100	606,247	2·062	"	"
32	819,400	593,854	*1·379	Geared.	Resistance in armature, compound.
33	975,200	474,170	†2·056	"	"
34	1,025,600	650,046	1·577	Direct.	Resistance in field, shunt.
54	1,273,000	739,903	1·720	Geared.	Resistance in armature, compound.
65	1,411,200	809,219	1·743	"	"
67	899,984	579,646	1·552	"	"
69	1,115,200	707,100	1·577	"	"

* Maximum speed of press, 18 impressions per minute.
† " " " 25 " "

This clearly shows that the geared motor with armature control is not a back number. No law or rule can be given as to which is the most economical method, owing to the wide range of conditions entering into the solution of each problem; this should be intrusted to a competent engineer to decide.

Adherence to simplicity, avoiding all complicated methods of control consistent with economy of current consumption, produces the most satisfactory commercial conditions.

Controller should be of the barrel type, compact, having all contacts inclosed and protected. This should be provided with only *one* handle, and having five or six speed contacts with two points reverse. The necessity for limitation to one handle is that two will produce confusion

when quick action is required; if operator is told to do this and then that, he generally does that, then this. With one handle a demand for instant reversal is quickly responded to, as there is but one thing for the operator to do—*i. e.*, push the handle in the opposite direction from existing conditions. This very soon becomes instinct with the press-feeder and mistakes are unknown.

The controller should be so made that it can be easily repaired and inspected, provided with ample carrying capacity and liberal surface contacts, allowing not more than 40 ampères to square inch; cylinder should be convexed and fingers concaved; where large quantities of current are to be carried by fingers, the latter should have copper braid connecting tip with base; larger size controller should be provided with special contacts for breaking current, not depending upon them to carry current while in constant service—this will reduce heating to a minimum; it must be easily handled and free from breakdowns.

When a first-class controller has been produced, the manufacturer has won half the battle, for herein has been one of the greatest sources of trouble the printer has had with individual motors, viz.: getting suitable control coupled with a substantial and reliable controller.

Reduce all automatic devices to a minimum, if not dispensing with them altogether on the controller; they are unnecessary, and as such are sources of trouble. A quick brake reduces sparking, thus lessening the chances of undue heating of contact fingers while in use—its adoption is an advantage.

Push buttons about a press, which is hand-feed, are superfluous and should only be used in connection with automatic feeders.

The great range of speed stipulated by some is seldom used in actual practice; ranges of running speeds from ten to thirty-five impressions per minute, as I see discussed, are so rare in large commercial houses as not to be worthy serious consideration. Cut work is not done at the high rate of speed of common job presses, nor are the same presses used for both classes of work and expected to pro-

duce the best results. Running the press at high rate of speed would soon make it unfit to do first-class half-tone work upon. And running common job printing on slow-speed cut presses would not pay. What is necessary in determining the range of speed of a press is the knowledge of the class of work to be done most thereon and how it is to be fed. A general knowledge of presswork and common sense will, as a rule, settle these problems satisfactorily.

If extreme limits are insisted upon, the proprietor must suffer and take what he can get as to economy and first-class work.

Protection includes a larger field than the electric motor—the printing press and operator should be fully considered.

Experience has developed the fact that satisfactory protection is secured only by means of an automatic circuit breaker; this applies not alone to the motor, but the printing press and its operator as well.

In the individual application of the electric motor, in most cases, the price of the motor is small, compared to the machine to which it is attached. For instance, the cost of an ordinary two-revolution front or back delivery flat-bed press, book size, is about ten times that of a first-class electric equipment for same, installed complete in every respect.

The motor will stand more rough handling than either the printing press or the operator, and still be in condition to do its work properly, conclusively showing that more than the protection of the motor is demanded. The results of the exclusive use of circuit breaker for printing press work are the reduction of repairs on presses 50 per cent., stoppages practically eliminated, with prolonged life of machinery. Presses can be handled promptly from any position, with circuit breaker set at 50 per cent. above capacity of the motor, providing the press is in free running condition; if it is not, the circuit breaker is the best telltale extant. The failure of the pressman to properly clean and oil his press is followed by a frequent opening of the circuit breaker, showing something is wrong and needs attention.

A personal experience in this line may help to explain more clearly the point in question.

Shortly after equipping some of the first presses in the office, constant complaints were received from one especial press, that the motor was not working satisfactorily, power unsteady, press would not start unless assisted by a laborer, circuit breaker was a nuisance, as it opened constantly. This continued until the press refused to work at all—motor was unable to turn it over. Investigation showed the main press shaft to be fast in its bearing, the pressman having failed utterly to oil or care for the press.

Henceforth we were not in receipt of complaints from that press; the ability of the circuit breaker to show up so clearly carelessness on the part of the workman established for itself a reputation which is still of the highest.

Injuries from rough handling and sudden starting are very materially eradicated. The impact from a blow four or five times the capacity of a motor, which a fuse permits, must expend itself somewhere; if it does not break a part, it strains the entire press, and constant repetition means lost motion in running gear—this is fatal to good printing.

This was such a serious objection to the individual connecting of electric motors to printing presses, that one of the oldest and most prominent press builders in this country came out flat-footed against this method, and said we must have a belt as a driving gear, for this would slip or run off the pulley; gearing meant the wreck of the press if anything went wrong. They were right when fuses were the only method of protecting the press, as they were not quick enough to prevent trouble. But with the use of a reliable circuit breaker all these objections are swept away, and we have better protection a hundredfold than slipping belts.

One word about the protection of the employés before leaving this subject. Carelessness bred by familiarity is the great source of danger to the majority of employés, and lessening of results from this demands thoughtful consideration. By way of illustration I will narrate two such instances, which have come under my personal observation.

(1) A laborer was cleaning a press, while in motion, with cotton waste; this caught in the gear wheels, drawing in his hand. The circuit breaker opened promptly, owing to the increased power necessary to overcome the resistance of his fingers between the gears. The press stopped before the entire hand was drawn into the moving machinery—three fingers only being hurt, one sufficiently to need amputation. Had fuses been the protection instead of a circuit breaker, nothing could have saved this man's entire right hand.

(2) A young lady passed too close to some moving machinery—a place where all passage was prohibited, on account of the closeness of rapid-moving presses—her dress skirts in some manner became entangled in the moving gear wheels, drawing her over against the machine; the quick opening of the circuit breaker stopped the press, with a result to her of a torn dress and a nervous shock.

The results which would have occurred in both instances, had circuit breaker not been in use, are sufficient to justify the employés in expecting that the highest type of protective devices will be used wherever possible.

The flexibility of the circuit breaker, in that it protects more than the motor, saving during the year in repairs more than its cost, clearly shows that it is a wise investment.

When installing an individually equipped printing press, the printer should insist on its use.

Maintenance.—Under this heading offices of reasonable size only will be considered, also assuming that presses are in constant use. Here the most satisfactory course to pursue is to have the care, inspection and responsibility of maintenance located at one source. One man should be intrusted with this work; a little study in systematization will accomplish all this while presses are "making ready," or at least so as not to interfere with work of production.

Inspection once in two weeks or once a month will do, in offices not too busy; this will keep down repairs, and, most important of all, keep the plant in A1 running condition, ready for anything.

Leaving care of motors to pressmen and laborers is a bad practice for everyone but the repair man. Not alone will the repairs increase, but, most serious of all, the press stops earning money when out of order, and at $10 or $15 a day this becomes expensive.

A good man who is able to turn off commutators, keep controllers in order and has a general idea of the electrical and press equipment, will pay for himself many fold during the year.

Small offices, like our branch offices, we look at once in two months.

Cost depends on what you are able to secure the services of such a man for—$2.50 to $3 per day.

Records should be kept of all repairs made and material used, if exact cost of maintenance is desired. This provides means of tracing where delays occur, whether in press proper or its driving motor.

Cost of Operation.—Herein figures can be used to obtain nearly any result desired, unless we demand full particulars, necessitating elaborate statement of all existing conditions. Having made most careful tests, the manufacturer cannot be guaranteed that his plant will operate within test figures, unless all conditions in commercial work are similar; these are impossible, so we are forced to make a test covering months of work, striking a balance from the results obtained; these will give average commercial figures, which in most cases will show an increase over a short test under favorable conditions.

To realize how much depends on the pressman, I desire to call attention to some facts with regard to two new presses recently installed in our office. These were "Century" two-revolution front delivery, bed 43 x 56 inches; connected to each press was a C-W, 2-100 compound motor, speed 130 to 230 revolutions per minute.

All went well for a month or so, then complaint was made that one of the presses ran slower the longer it was in operation. An examination disclosed the fact that the motor was apparently not large enough for the press, as the fields and frame became so warm that the hand could

not be held on it for any length of time. Speed dropped from 180 to 140 revolutions per minute, after which circuit breaker was constantly opening, and it became necessary to shut down press every two hours or so that motor might cool off. A test showed that the press took 46 ampères at 120 volts; speed, 144 revolutions per minute; this was on fifth speed; moving handle to sixth and last point with circuit breaker set at 58, latter would open every time; this was reset at 70, and ammeter indicated 60 when change was made to last speed; current used, 48 ampères at 160 revolutions per minute. Press labored and did not run smoothly.

On examination, we found that the track gibbs had been set up too close; after properly adjusting these and having press thoroughly oiled, we increased speed to 180 revolutions per minute, current consumed dropped to 30 ampères; even then the press was stiff, for its companion was running at 182 revolutions per minute on 22 ampères, both doing same class of work.

This showed the press was taking 60 per cent. more current than it should had only ordinary care been used, while it was consuming 100 per cent. more than its duplicate, working under similar conditions.

A commercial figure ought to show an increase of 15 to 20 per cent. over efficiency test.

A hurried glance at the comparative cost of operating belted, geared and direct-connected motors is desirable, although a complete analysis is impossible to include in this paper owing to its length.

Belted motors, unless grouped, will not be considered, as they have no commercial standing for economy.

First, considering grouped presses of medium size, running from main line shaft, driven by a single motor. A line of drum cylinder presses of various makes, operated by belting afterwards driven by individual motors, gives actual commercial condition worthy of comparison. Taking, for example, thirteen drum cylinder presses in a row, with belting reduced to a minimum, a large motor belted to center of shaft, thus distributing load equally on hangers;

using a 15 horse-power motor, so with all presses at work motor is running at about 75 per cent. load—very favorable conditions.

During two months these presses made 2,892,175 impressions, consuming 1,601,200 watt hours, or an average of ·553 watt hour per impression.

As soon as possible after equipping these presses with 2 horse-power geared motors wattmeter records were taken. For four of the heaviest running presses, a six months' continuous test showed the following:

Impressions, 3,813,542. Watt hours, 1,851,100, an average of ·485 watt hour per impression, a saving of 14 per cent.

While disconnecting presses one by one, to equip same individually, the average consumption per impression for the remaining presses increased very rapidly. With five presses working we used between 50 and 60 per cent. more current per impression.

Geared vs. Direct shows that up to 5 horse-power the geared is more economical. In 5 to 15 horse-power, there is not much difference. Economy of operation should not be the guiding spirit in the selection of motors of these sizes. From 25 horse-power up, the direct motor has many advantages, especially for newspaper work.

Cost of Presswork.—A web press, printing at the rate of 6,000 impressions per hour—this includes cutting, folding and printing four signatures of 16mo or 64 pages, including all stoppages—will produce in a day 2,304,000 pages, an average of 384,000 pages for each hour. The average current, including "make-ready," etc., is ·7 watt hour per impression; 91,428 pages per hour per kilowatt; at 5 cents per kilowatt hour, there will be printed, cut and folded 18,285 pages for 1 cent.

A good day's work for a flat-bed press, bed 42 x 52 inches, running at 20 impressions per minute, is 8,400 impressions in eight hours, of 32 pages each, with a total of 256,000 pages for the day.

Average current consumption is 1·5 watt hours per impression, or 21,333 pages per kilowatt hour; at 5 cents per kilowatt hour is produced 4,266 pages, as against 18,285 by

the web presses for the same money (1 cent), making an output for the webs four and one-half times that of the flat-bed presses, with same current consumption. The quality of the work of the former is not always as good as the latter, yet is more than compensated for by the folding and cutting.

A card-press, which prints both sides, making slitting and cross-cut from a web of cardboard, is not a usual press. The following is the output and power consumption for five months:

Impressions	8,362,750
Kilowatt hours	580·6
" " per impression	·0694

Four cards being printed at each impression, there was a total of 33,451,000 cards. With current at 5 cents per kilowatt hour, 11,500 cards were printed for 1 cent.

Main Pressroom, Government Printing Office.—In this room are forty-nine presses, including three large web presses; of the balance one-half are large-size book presses, the remainder of double-medium size, attached to which is an aggregate of 190 horse-power in motors.

During the month of November, 1898, the presses made 5,403,032 impressions, consuming 6,542·8 kilowatt hours, an average of 1·21 watt hours per impression.

6,542·8 kilowatt hours at 5 cents, $327.14; or 165 impressions, allowing 12 pages for each impression, we have 2,000 pages for 1 cent.

Power Plant, Government Printing Office.—The entire power, exclusive of heating, lighting, fans, etc., consumed during the month of December, 1898, from 8 A.M. to 4 P.M., during 27 working days, 22,516 kilowatt hours, 834 kilowatt hours per day, or 104 kilowatts per hour. Connected to the power circuits are 700 electric horse-power, including electric elevators; 575 electric horse-power, without electric elevators. Daily consumption is about 100 kilowatt hours for elevators, thus giving the following ratios:

5·1 horse-power connected to power used.

6·2 horse-power connected (exclusive of elevators) used.

Largest swinging power load we have ever had is 180 kilowatts, or a ratio of 2·9.

Current consumption during November, 1898, for foundry, 3,025·2 kilowatt hours, average 12·2 per hour; folding room, 1,295·8 kilowatt hours, average 5·4 per hour; bindery, 1,875·2 kilowatt hours, average 9·7 per hour.

Advantage to be gained from changing over from belting to individual electric motor for printing-press work is not alone in power saved, but better grade of work, less spoiled sheets, cleaner, healthier rooms for employés, less repairs to machinery, and, most of all, an increased product without a corresponding decrease in value of presses by running at too high speed.

Output of the government printing office pressroom has been increased 15 per cent. A few calculations will show what this means in an establishment operating continuously 100 presses, each earning, at the smallest figure, $10 per day, or $300,000 for the year. 15 per cent. of this is $45,000, a sum that makes the saving in motive power dwindle into insignificance. A few years will pay for the entire electric equipment, including the lighting.

If there is any printing office in the country where a reliable power must be had, it is the government printing office. We run 24 hours daily during Congress, and keep lights going throughout the year, never shutting down our power plant. We issue a daily paper, the *Congressional Record*, having to catch mails same as any other daily. Then all bills introduced, together with the proceedings of Congress the day before, have to be on each member's desk by 10 A.M. To this must be added the printing furnished the various branches of the government, consuming a daily average of 25 to 30 tons of paper.

Our recent war with Spain has made demands in excess of anything heretofore.

At the end of the recent popular bond issue, the Treasury Department wanted 2,000,000 copies of circulars Monday, copy for which was received late Saturday. They had wagon-loads waiting at their doors Monday morning. This is but one instance of many we have been called upon to execute.

There has never been a hitch in the motive power; not a motor has given out. In fact, such a freedom from interruption of power has never been known in the history of the office as during the past three years, or since we have adopted electric power.

The most brilliant achievement during the year was the printing of the "Maine Report." "This consisted of 298 pages of text, twenty-four full-page engravings and one lithograph in colors, and although the originals of the illustrations were not in the possession of this office until 3 o'clock P.M. of March 28th, and the manuscript of the text was not received until 6 o'clock P.M. of the same day, complete printed copies, in paper covers, were placed upon the desks of Senators and Representatives by 10 o'clock of the following morning."

In the treatment of this subject, necessarily many times subdivided, I have tried to mention, in a brief way, all essential points, a detailed consideration of which would exceed the limits of this paper, yet hope in the future, at your discretion, that these may be clearly explained by illustrations and carefully prepared tables of data now in course of compilation.

THE FRANKLIN INSTITUTE.

Stated Meeting, held Wednesday, April 19, 1899.

IMPROVED METHODS FOR THE PURIFICATION OF SEWAGE AND WATER, AS SHOWN IN THE OPERATION OF THE MUNICIPAL PLANT AT READING, PA.

BY JOHN JEROME DEERY,
Architect and Engineer, Philadelphia, Pa.

(*Concluded from p. 239.*)

During the winter seasons the plant has been in continuous operation, notwithstanding very hard freezing weather. The temperature has frequently been below zero. Last winter, during the blizzard, the temperature was below zero

for several days, and fell one day to 19° below zero. For thirteen consecutive days it was below the freezing point. On February 10, 1899, the thermometer registered 14° below zero for twenty hours. During the winter, when the liquid is shut off a compartment, and it has percolated through the beds, there is formed an ice coating to columns and girders below it, and from the bottom of the beds icicles become pendant. The surface of the top of the compartment becomes frozen for a few inches in depth. At the same time the lower beds are not affected, as the ice falling into the moving water is broken up and melted. Not a pound of ice has ever been carted away from the plant. All other compartments of upper beds and of the lower beds are working and filtering the water under these and all conditions. The liquid is seldom less than 45° temperature, and when the liquid is distributed upon the compartment out of service, from its warmth it soon penetrates the surface of the bed, and within ten minutes the bed will be running as usual, and all icicles will have dropped into water below on lower beds.

The water then flows from the underdrains or gutters over metal disturbers which further aërates it, and then passes into the broad and shallow cement channel, where in transit for nearly 900 feet it receives the benefit of light and air. Then it discharges through a 24-inch terra-cotta pipe for 1,000 feet into an arm of the Schuylkill River—clear, pure, sparkling and odorless water.

The absolute elements that are essential to perfect water or sewage purification are combined and provided within the plant, viz.: sand filtration by gravity without the aid of chemicals; constant aëration and oxidation; exposure of water in shallow depths to the sunlight; culture beds to promote healthy, active micro-organisms for complete nitrification, or conversion of animal and vegetable matter into harmless mineral matter.

The effluent discharged from this plant into the river, by its varied acts, is chemically and bacteriologically pure to a standard in excess of 99 per cent. over that of the original impure and foul liquids. As at the pumping station, there

is not any offensive or unpleasant odor arising from the operation of the plant.

This process is fully protected by patents in the United States, Canada and European countries, issued to John Jerome Deery, the inventor.

Crude sewage may be applied to this plant at the rate of 12,000,000 gallons per acre daily, undergoing transformation that makes the water of the effluent more pure and wholesome than is to-day supplied as drinking water to most of the cities and towns of the United States and Canada.

The pumping station has been in active operation since February 3, 1896, and the filtration or purification station has been in active operation since November 20, 1896.

THE PENNSYLVANIA SANITATION COMPANY, 1110 BETZ BUILDING, PHILADELPHIA, PA.

BACTERIAL ANALYSES.

Date of Analyses.	Number of Samples.	Different Points During the Purification Process.	Bacteria per Cubic Centimeter.		Percentage of Bacteria at Different Points, as to Number Applied.	Percentage of Bacteria Removed.
			In Applied Sewage.	In Water at Each Point.		
Oct. 9, 1896	1	Crude sewage	27232·8	—	—	—
	2	Sewage through the coke filter	27232·8	19152·4	70·32	29·68
	3	After filtration through upper filter beds	27232·8	516·6	1·89	98·11
	4	After aëration below upper filter beds .	27232·8	126·0	·46	99·54
	5	After filtration through lower filter beds	27232·8	22·0	·08	99·92
Oct. 19, 1896	1	Crude sewage	49867·3	—	—	—
	2	Sewage through the coke filter	49867·3	16542·7	33·17	66·83
	3	After filtration through upper filter beds	49867·3	232·6	·46	99·54
	4	After aëration below upper filter beds .	49867·3	81·2	·16	99·84
	5	After filtration through lower filter beds	49867·3	·2	·0004	99·9996

CHEMICAL ANALYSES.

PARTS IN 100,000.

Date of Analyses.	Number of Samples. *	Chlorides.	Total Hardness	Oxygen Consumed in the Moist Oxygen Process for Determining Organic Matter.	Free Ammonia.	Albuminoid Ammonia.	Amount of Nitrogen as Nitrates and Nitrites.
Oct. 9, 1896	1	9·	15·54	3·947	·34	·14	·429
	2	6·4	15·54	2·187	·27	·09	·650
	3	6·4	16·095	1·125	·022	·02	·673
	4	6·4	16·65	·937	·019	·015	·787
	5	7·	16·65	·812	·010	·025	·984
Oct. 19, 1896	1	6·5	16·095	16·000	·590	·730	·420
	2	6·5	16·650	4·000	·370	·060	·305
	3	6·5	16·650	2·000	·055	·025	·910
	4	6·5	17·760	2·000	·065	·040	·951
	5	6·5	17·760	1·800	·010	·055	·972

* The numbers are identical with those stated for bacterial analyses, thereby indicating the different points from which were taken these samples.

Remarks.—While the above figures speak for themselves, there is no reason for our not calling your attention to the remarkable reduction in the number of bacteria which the process seems to assure in removing, in the last series for example, over 99·99 per cent. of the bacteria disappear during the purifying process. The chemic study shows the enormous reduction of the free and albuminoid ammonias and the rise of the nitrites and nitrates, thus converting, to a large extent, suspicious compounds into salts of which we feel no anxiety.

Respectfully submitted,

W. M. L. COPLIN, M.D.,
H. F. HARRIS, M.D.

[Compiled from the Report of Drs. W. M. L. Coplin and H. F. Harris, Professors of Pathology and Bacteriology at the Jefferson Medical College, of Philadelphia. (Dr. Coplin is the Chief Bacteriologist to the State Board of Health of Pennsylvania.) The first analysis was made after the plant had been in operation only ten days. The second analysis was made after twenty days' operation, showing increased efficiency with continued use. Attention is especially called to the remarkable showing evinced by the enormous reduction in the number of bacteria present in the sewage at the second analysis, from nearly 50,000 to but a small fraction of 1 to the cubic centimeter.]

CHEMICAL ANALYSIS OF EFFLUENT.

PARTS IN 100,000.

Date of Analysis.	Appearance.		Odor.		Ammonia.		Chlorides.	Nitrogen.		Hardness.
	Turbidity.	Sediment.	When Cold.	When Hot.	Free.	Albuminoid.		Nitrates.	Nitrites.	
Feb 13, 1897	None	Slight	Earthy	Faintly	·0480	·0142	5·76	·2400	·0030	32·0

[Compiled from the Report of Mrs. Ellen H. Richards, of the Massachusetts Institute of Technology, Boston, and chemist to the State Board of Health of Massachusetts.]

The cost of the site for the pumping station was $15,000; the pumping station, including all machinery and finish of grounds, cost $75,000; the site for the disposal plant, with right of way for pipe line, cost $8,725; and the filtration station was fully equipped and completed at a cost of $100.000. The total investment, therefore, was $198,725.

The sets of bacterial and chemical analyses herein contained were made by Dr. W. M. L. Coplin and Dr. H. F. Harris, Professors of Pathology and Bacteriology in the Jefferson Medical College, Philadelphia. Dr. Coplin is the chief bacteriologist to the State Board of Health of Pennsylvania. Chemical analysis was also made by Mrs. Ellen H. Richards, of the Massachusetts Institute of Technology, Boston, and chemist to the State Board of Health of Massachusetts.

After ten days' continuous operation of the purification plant, samples were taken at various parts of the structure. The crude sewage contained 27,233 bacteria to the cubic centimeter, and the effluent, 22 bacteria to the cubic centimeter. Ten days thereafter, or after twenty days' continuous operation, the crude sewage contained 49,867 bacteria to the centimeter, and the effluent, ·02 bacteria to the cubic centimeter.

It is obvious that when foul house sewage, reeking with all kinds of filth, garbage and wastes from buildings, is converted into pure water, as demonstrated by the operation and analyses of the plant at Reading, the purification

of a polluted river serving as a water supply to a town or city is by comparison a simple and easy problem of solution by this process to produce an absolutely potable, bright, clear, sparkling water, free from all color, sediment and disease-producing bacteria.

The truth of these results and the satisfaction attending them have been verified in various ways by the Mayor, Board of Public Works, City Engineer and Sewer Committee of the city of Reading, Pa., as also by State Board of Health of Pennsylvania, Boards of Health of the city of Philadelphia and of the city of Reading, Pa.

During February, 1897, I noticed that the upper bed had become almost blue and black in colors, and that by placing the nostrils directly under the bed a peculiar odor was apparent. I desired an immediate analysis to learn the component parts of the mass. A covered can was sterilized and a section of the upper bed was lifted out and placed in the can in exact position it occupied in the bed. Within a few minutes a train was boarded to Philadelphia, for the laboratories of the Jefferson Medical College. Doctors Coplin and Harris began at once an analysis. On February 15, 1897, they reported that "each gram contained 18,581 bacteria, that 33 per cent. are moulds, 22 per cent. are growth of hay bacillus, 5 per cent. are micrococcus pyogenes aurens, 2 per cent. micrococcus pyogenes albus, and the remainder (38 per cent.) are nitrifying bacteria, both identified and unidentified.

"The dark color seems in all probability to be due to oxidizable organic matter, as it is immediately dispelled by an oxidizing agent, even exposure to air accomplishing this effect." (Signed) W. M. S. Coplin and H. F. Harris.

Some of the best known bacteriologists and chemists I herewith quote as a proof of the purifying agents of light, air and of the action of hardy nitrifying bacteria.

Dr. Palermo, Naples, Italy, says: "Sunlight is a microbe-killer, especially those that are noxious to human or animal life."

M. Marshall Ward, Percy F. Frankland, Mr. Buchner and Mr. Kotljar have proven by demonstration that water is

purified by light. Moreover, the experiments prove that the bacteria spores are really killed and not merely retarded in development. These specialists state generally that there is one natural agency, at least, which destroys anthrax spores in surface water, viz., the action of direct sunshine.

M. P. Leonard says: "Water falling in drops upon water or wet bodies generates electricity, the water becoming positively electrified. The essential conditions of electrification are the concussions among the drops themselves and against the wet rock, etc."

Professor Esmarch says "that sunshine is the best of all disinfectants and disease germ destroyers."

Professor Koch and Professor Pasteur, of Paris, since their early investigations, have maintained and confirmed similar conclusions.

Dr. Dupree, of London, England, says: "The aerobian and atmospheric forms of life could be caused to grow particularly near the surface. If the sewage were well aërated before, during and after treatment, it would be certain that the microbe life would assume that form which produced the least objectionable by-products. Aerobic bacteria effect complete decomposition of the organic matter in water or sewage, which is nitrification, or a conversion of organic and inorganic matter into nitrates and nitrites."

Mr. Geo. W. Fuller, biologist, late in charge of experiment station at Lawrence, says: "that only the non-pathogenic bacteria find their way through the filters, and the germs of disease early succumb to the unfavorable conditions found in the sand bed. The few bacteria found in the effluent belong to the hardy species of water bacteria, many of which exist in spores. The evidence now at hand shows that the disease-producing bacteria are among the first to succumb, because farthest removed from their natural habitat."

The noted German experts on analyses of water, Fraenkel and Piefke, assert that "every surface water before it is used for drinking purposes should be freed from all infectious substances. For this purpose, whenever large quantities of water are to be treated, sand filtration is at present the most convenient and effective method."

Prof. Thos. M. Drown, President Lehigh University, says: "In the first quarter of an inch of a filter bed, the bacteria are present by the million, and that the number rapidly decreases as depth increases, and that at the depth of a foot there are very few within it. The work of a filter is mainly done in the upper 3 or 4 inches."

In the autumn of 1894, a number of papers were read by sanitary experts as a result of their experiments before the Société de Biologie, and shortly thereafter at the International Congress of Medical Societies, at Rome, Italy. The following are quotations from them:

"Cold acts quite promptly on microbes, checking their development and secretions; but, in order to destroy them, we have to go down to extremely low temperatures; even at 60° below melting ice refrigeration has to be continued for a number of hours in order to annihilate micro-organisms. These results enable us to understand why, in contradiction to what is usually believed, epidemics break out in spite of rigorous winter weather.

"Heat is more effective; and yet to sterilize completely—that is to say, to kill all germs and their spores, and render their secretions harmless—it is necessary to reach or exceed a temperature of 200° C.

"Of all the physical agents that surround us *light* is, from a practical point of view, the most interesting and perhaps the most important as regards the present subject. With the other agents—pressure, cold, heat, etc.—in order to kill microbes by their action, we are obliged to apply them under abnormal circumstances. But *light*, as it exists about us, is very energetic, and its effect manifests itself whether it comes from the sun or from an electric arc."

Dr. Park, of New York, says: "The ruling entity of zymotic or germ sickness is the microbe lurking in all dark, mouldy and unclean places. Its quickest destroyer is the sunbeam, aided by currents of fresh, pure air."

In experiments by Professor Buchner, he says: "Cultures of typhoid and other bacilli placed in water were completely destroyed in three hours by bright sunlight, and rapidly reduced even by diffuse daylight, although they

rapidly increased in the dark. To determine the depth at which this bacteriological action of light ceases, partially exposed cultures of different bacteria were sunk in Stamberger Lake, near Munich. At three yards below the surface the retarding effect was only just perceptible, although it was shown, ten years ago, that light penetrates in water—at least in the Lake of Geneva—to depths as great as 185 yards. It is apparent, therefore, that the effect of sunlight in purifying rivers has been overestimated, and is confined to the surface."

The conclusion and recommendation of experts recited, as well as that of my own experience and investigations, cause me to announce that they may be all embodied in a plant to purify the entire water supply of the city of Philadelphia. With that object in view, all data pertaining to the subject has been secured and drawings have been made to incorporate substantially all the best features of the suspended screening chamber, and the filtration beds as installed and in operation at Reading, Pa. The screening chambers can be placed at the intakes or at the filter beds receiving the water from the pumping mains. The latter is more preferable than the first. The water from the pumping mains would be received into a series of distributors, as shown by the illustration. These distributors would receive the benefits of light and air. The water would pass over the edges in thin films, and thence over a series of splash plates, when the water would reach the upper grating of the suspended screening floors, in an aërated condition.

The suspended screening floors would consist of layers of breeze coke, 12 inches deep, supported on a lower grating, with wire netting over the same, while the upper grating would serve the purpose of holding the breeze coke in place and to prevent floating. It would be arranged in sections for removal. The water in its transit would be distributed over the entire area of the suspended coke beds. The water would percolate through the coke beds, and drop from the lower grating onto a collecting floor, which would serve the purpose as the supply chamber to the mains and distributors

of the filter beds. The coke in the screening chambers will absorb large floating matter as well as considerable of the largest matter in suspension. At the same time it will remove from 25 to 30 per cent. of all bacteria. The suspended screens will be supplied with a liberal circulation of air both above and below. After running for a couple of weeks, the upper gratings would be removed, as well as all matter adhering to it, and about 4 inches in depth of coke breeze, this material, of course, serving the purpose of fuel for the pumping stations that are established in the high level distribution, and the remainder could be sold and removed as fuel. The water on the collecting floor, which has been partially purified, will then flow by gravity to the mains supplying the various compartments of the filter. The filters will be constructed of iron or masonry or combination of embedded steel and concrete. They will be divided into 1,000,000 gallon compartments, and will be elevated above the ground, as shown by the illustration, with the addition of a roof and sides. The water will pass through the laterals and distributors. The water will be exposed to the light from abundant skylights, and, as it flows over the edges in a thin film, it will be thoroughly aërated. In its descent it will strike on splash-plates or screening slats, which will separate the liquid into small particles. The composition of the beds in all particulars will be the same as those at Reading. The structure, where placed in the Park adjacent to the reservoir, can be treated architecturally in a way to satisfy the lover of the æsthetic as well as of the practical, since due consideration will be given to the site chosen. It is possible in some places to provide shelters or pavilions for the use of the people in combination with the filters.

The water, on reaching the surface of the filter bed, will make the usual deposit and form the gelatinous surface over the sand which is formed in combination by the action of the hardy scavenger bacteria within the bed as well as the matter in suspension which is deposited thereon. It will be readily seen that the air penetrates the beds to their full thickness, since the air is in circulation both below and

above the bed. The healthy micro-organisms therein established are enabled by this means to perform their functions in bringing about a conversion of all organic and inorganic matter into harmless mineral products. There is no pressure of water above the surface other than depth contained, which would be about a foot. There will be no wasting of water, since washing will at no time be necessary for the filter, nor are chemicals used at any time during the process of purification of the water. The water, in trickling in small globules like rain from the under surface of the filter beds, descends through the atmosphere for 10 feet before it reaches the collecting floor and pipes, from whence it flows into the reservoir. By this means the water which has been sterilized is revitalized so as to make it sparkling and palatable. At the same time, should there be any pathogenic bacteria within the globules, they would be oxidized or burnt up in the presence of the oxygen in the air, while all gases in solution that would be in the water during the process of purification would be set free in the atmosphere.

The reservoirs of the city would be converted into and used as clear-water basins. All sediment, fish and other offensive matter would be by this process excluded from the reservoir. The water discharged from filters would be chemically and bacterially pure to an extent of at least 98 per cent. The other 2 per cent. soon die, since their nourishment has been removed in the process of purification. About every two to four weeks a compartment would be put out of use for cleansing purposes; the deposit formed on the surface, together with the sand that adheres to it, usually $\frac{1}{8}$ to $\frac{1}{4}$ inch in thickness, would readily dry and would be removed. It is possible to clean the sand by washing it, but more preferably by baking it in a revolving furnace, when it would be transferred to a fan or blower, so that the fine soot would be blown off and the sand discharged into bins, where it would be re-used on the surface of the filter beds as a substitute for that taken off previously. By this arrangement large piles or dumps would not be a product of the operation, and at the same time it would be economical in the operation and maintenance of the plant.

It is possible to construct these filter beds either within the reservoir or on suitable land adjacent to them. The city possesses 191·4 acres of basins at the water level. The area is more than double that required for the installation of these filter beds, while the embankment and land immediately adjacent are also sufficient in every instance to provide the filter beds, of adequate capacity to purify the water that is daily pumped or discharged into them.

The area required for the sand filtration process as established at Lawrence, Hamburg and London is 70 gallons per square foot of the surface. Our standard would be 280 gallons per square foot of surface, and for the suspended screening coke beds would be 3,000 gallons per square foot of surface. The water plant at Wilmington, Del., is on the basis of 1,000 gallons per square foot of surface. The chemical and pressure processes are from 3,000 to 4,000 gallons per square foot of surface.

I recite these areas in order to convey to your minds that the process proposed by the company for the city of Philadelphia is slow sand filtration by gravity, and that it has features containing the recommendation of the best experts and scientists of the world, which are notably absent in the plants at Lawrence, Hamburg and London.

These plants can be constructed for the entire water supply of Philadelphia at Belmont, Roxborough, East Park, Queen Lane and Wentz Farm, of a total capacity of 300,000,000 gallons per day, and would be in readiness for operation in less than twelve months; that is to say, complete in every particular, furnishing every water outlet in each person's residence or building with clear, bright, sparkling, odorless water, free from all disease germs, and chemically and bacterially pure to an extent of from 98 to 99 per cent.

That date would mark an epoch in the history of Philadelphia, for, practically, epidemics of typhoid fever and kindred diseases would become past history, and the comfort and happiness and health of the inhabitants would be increased, so that the city of Philadelphia would become the most healthful city in the world.

THE EFFECT OF SALT WATER ON CEMENT.

By A. S. COOPER.

The present article, while not pretending to go as thoroughly into this subject as others have done, will give the results of some experiments, which will go far towards settling a few points in this much-disputed question. In cold climates it is a general custom to put salt in the gauging water to prevent the mortar from freezing before it is placed in the works; and on the sea-coast it is often customary to gauge cement mortar with sea water rather than go to any extra expense to obtain fresh. The experiments given in this article were designed to determine whether or not this is good practice, and also to ascertain the effect of sea water on concrete structures. It was the intention to have them extend over a period of several years, but as circumstances interfered with the long-time tests, they were discontinued at the end of one year. They are, therefore, of very little value as showing the effect of sea water on engineering structures, but show conclusively the ill-effect of salt in gauging mortar.

DESCRIPTION OF TESTS.

Briquettes were made in moulds of the form recommended by the American Society of Civil Engineers in 1885, and the mortar rammed into them by a German hammer machine, striking 120 blows on each briquette, using about a 3-pound hammer and a 10-inch drop. The mortar was made as near a standard consistency as possible, water being added until it just appeared below the moulds, when the hammering ceased. All briquettes of like mixtures were gauged with the same per cent. of water. The mixing was done with a Riehlé mixing machine, using about 100 turns. Proportions were determined by carefully weighing each batch. The briquettes were stored in moist air for twenty-four hours and then placed in the immersion tanks, where they remained until broken. No at-

References to Diagrams.

Indicates briquettes mixed with fresh water and immersed in fresh water.
" " " " fresh " " " " salt "
" " " " salt " " " " salt "
" " " " salt " " " " fresh "

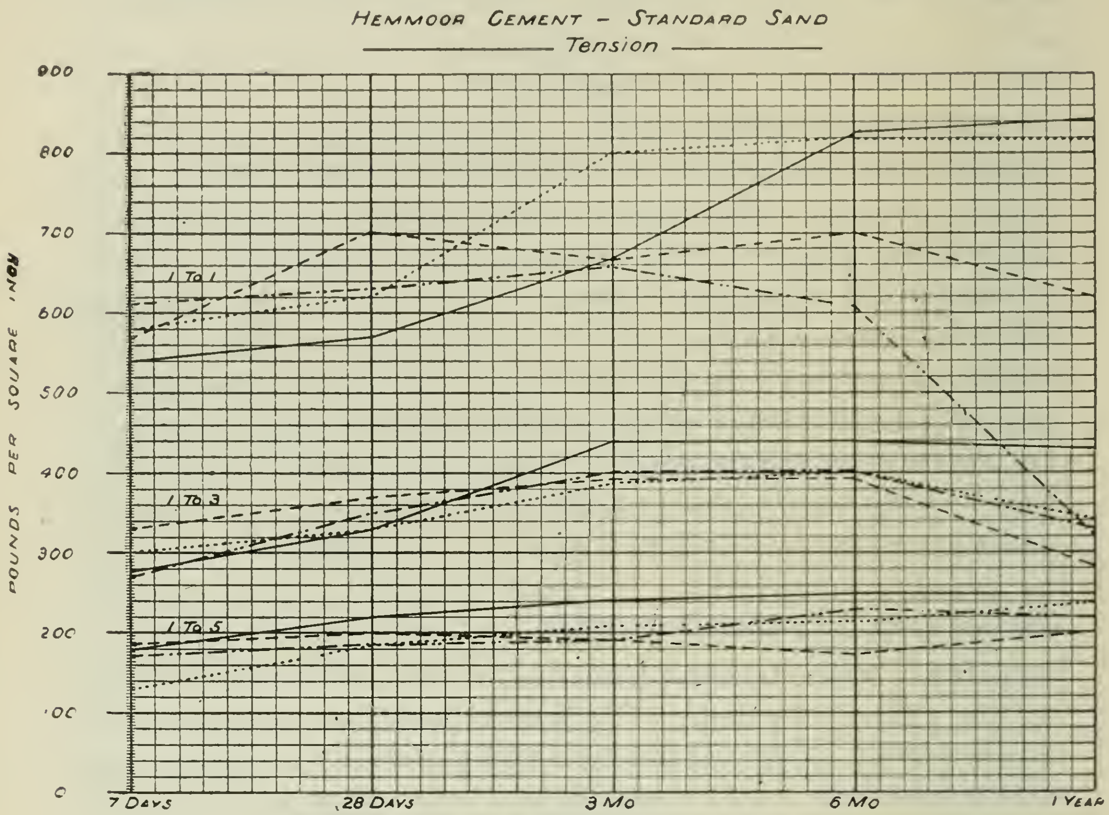

Diagram No. 1.

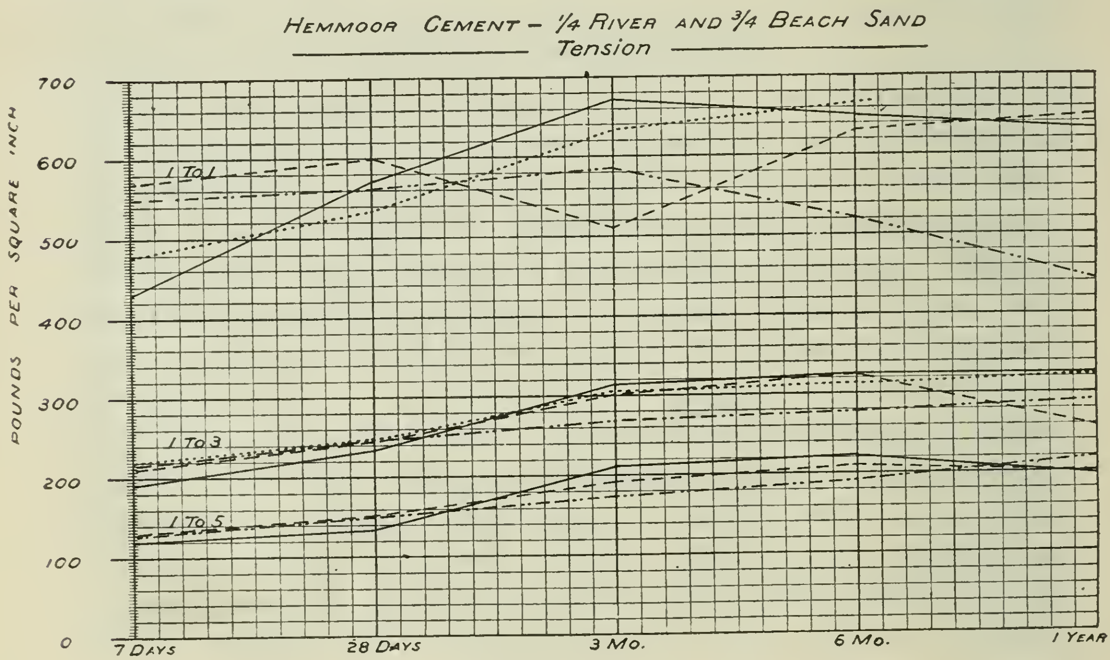

Diagram No. 2.

tempt was made to keep the tanks at a uniform temperature, but as the briquettes which were to be compared with each other were all made practically at the same time, the comparisons are still accurate without this precaution. The fresh water tank was renewed as often as the water became noticeably alkaline. The salt water tank was filled with sea water and only changed three times, but as the

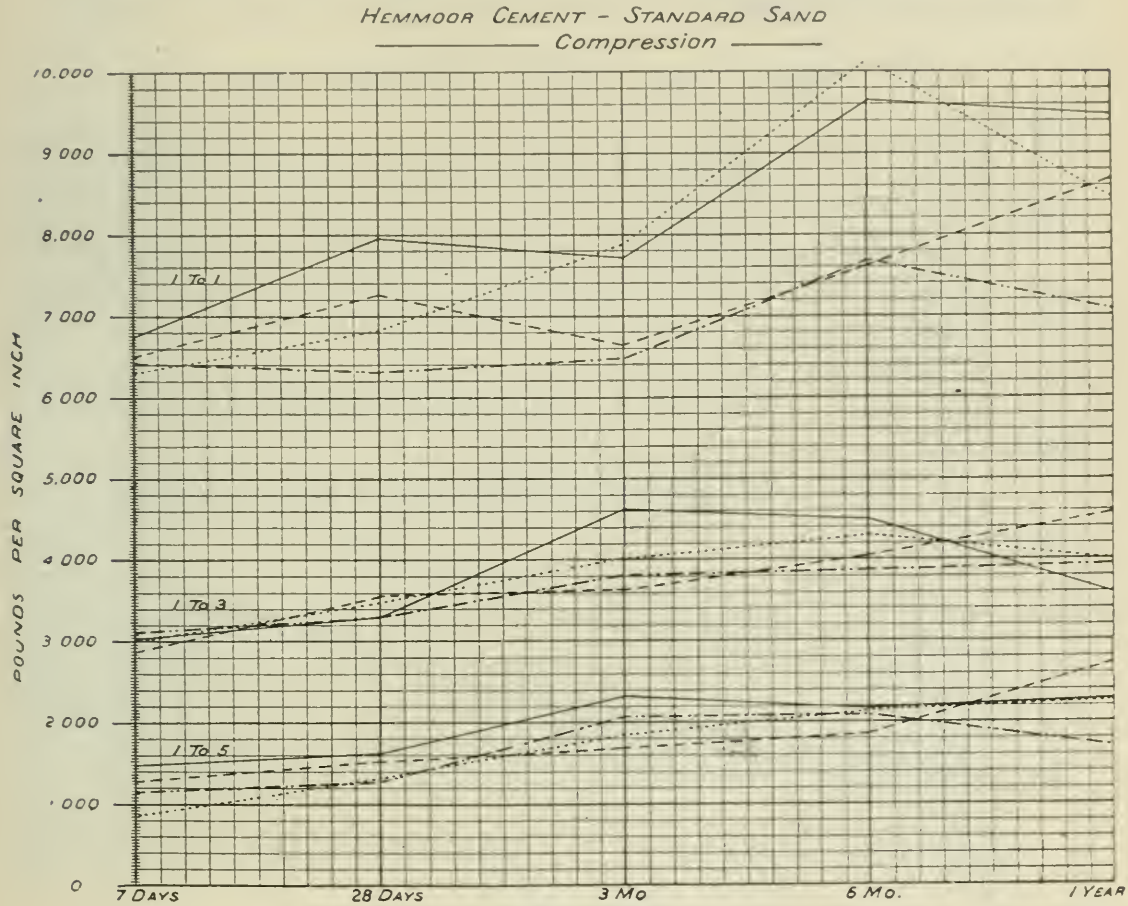

Diagram No. 3.

volume of water was fully 100 times the volume of the briquettes stored, it was not thought necessary to renew the water oftener. The briquettes were first broken on a Fairbanks tension machine, and then a heavy rubber band put on them to hold the two parts together, and crushed on a Riehlé machine, worked with hydraulic pressure. Series of tests were made with two brands of cement, one a natural and the other a Portland. In each case all of the ce-

ment came out of the same barrel. Sets were made with standard sand, and also with natural sand found in this vicinity. In the case of the natural cement, mortar was mixed in the proportion of 1 to 1, 1 to 2 and 1 to 3; and with the Portland, 1 to 1, 1 to 2, 1 to 3 and 1 to 5. A sufficient number of sets of each were made with fresh water and with salt, and each immersed in fresh and salt water to complete all of the different series given in the accompanying tables and diagrams. In each series some briquettes were

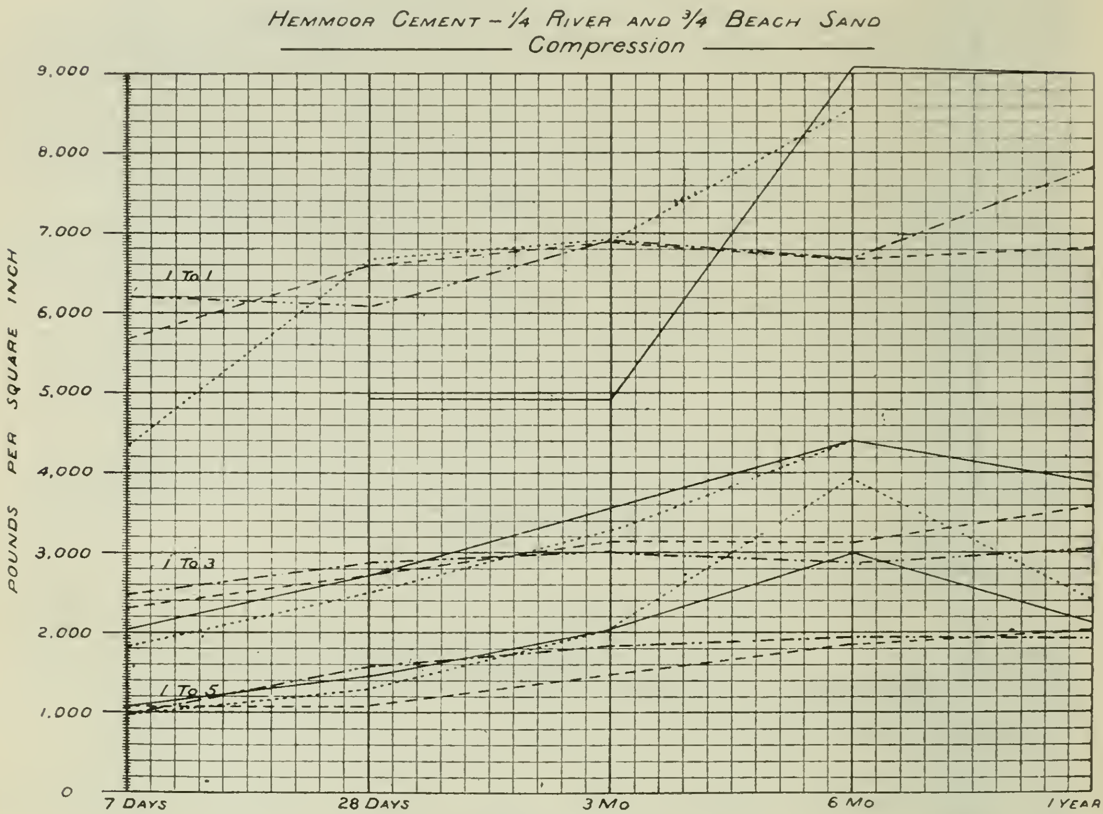

Diagram No. 4.

broken at 7 days, 28 days, 3 months, 6 months and 1 year. It was the intention to break some at the end of 3 years and 5 years, but this part of the experiments had to be abandoned. In the tables and diagrams, all strains are given in pounds per square inch of section or surface.

RESULTS OF TESTS.

By a reference to Table No. 1 and Diagrams Nos. 1 to 4, it will be seen that in case of the Portland cement the bri-

TABLE No. 1.—SHOWING RESULTS OF TESTS MADE FROM ONE SAMPLE OF PORTLAND CEMENT, TO DETERMINE THE EFFECT OF SALT WATER USED IN GAUGING AND FOR IMMERSION.

Sand.		Water.			7 Days.			28 Days.			3 Months.			6 Months.			1 Year.		
Kind.	Ratio to 1 of Cement.	Per Cent. to Dry Ingredients.	Gauging	Immersion.	No. of Tests.	Tension.	Compression.	No. of Tests.	Tension.	Compression.	No. of Tests.	Tension.	Compression.	No. of Tests	Tension.	Compression.	No. of Tests.	Tension.	Compression.
Standard	1	8·9	Fresh	Fresh	2	544	6779	2	574	7980	2	671	7734	2	833	9658	2	846	9485
"	1	8·7	Salt	"	2	585	6340	2	621	6808	2	801	7850	2	820	10188	2	819	8465
"	2	6·7	Fresh	"	2	487	6484	2	560	7200	2	584	6332	2	627	7580	2	587	7660
"	2	7·8	Salt	"	2	458	5666	2	507	5876	2	580	7175	2	630	7362	2	614	6850
"	3	7·8	Fresh	"	2	278	3038	2	335	3235	2	438	4602	2	444	4480	2	431	3594
"	3	7·8	Salt	"	2	303	2666	2	330	3587	2	391	4025	2	408	4325	2	344	4020
"	5	7·2	Fresh	"	2	182	1478	2	221	1606	2	242	2354	2	252	2092	2	252	2250
"	5	7·3	Salt	"	2	135	982	2	183	1368	2	212	1850	2	216	2188	2	243	2288
¼ River ¾ Beach	1	10·0	Fresh	"	2	434	—	2	571	4981	2	674	4932	2	657	9131	2	636	9040
"	1	10·1	Salt	"	2	479	4378	2	535	6679	2	637	6875	2	662	8618	—	—	—
"	2	9·3	Fresh	"	2	285	3475	2	350	4175	2	413	4775	2	447	7175	2	505	7134
"	2	9·7	Salt	"	2	339	4025	2	405	4017	2	439	5425	2	459	6194	2	487	5630
"	3	9·3	Fresh	"	2	193	2012	2	236	2736	2	317	3570	2	312	4395	2	324	3880
"	3	9·4	Salt	"	2	210	1812	2	260	2500	2	304	3250	2	323	4400	2	326	3930
"	5	9·3	Fresh	"	2	120	1100	2	135	1468	2	211	1970	2	222	3200	2	198	2140
"	5	9·4	Salt	"	2	136	1000	2	155	1294	2	194	2025	2	199	3965	4	208	2396
Standard	1	9·4	Fresh	Salt	2	568	6502	2	709	7256	2	670	6640	2	708	7655	2	625	8706
"	1	8·7	Salt	"	2	618	6436	2	631	6325	2	660	6462	2	610	7700	2	318	7107
"	2	7·3	Fresh	"	2	477	5419	2	586	6590	2	600	5678	2	637	7461	2	471	7171
"	2	7·7	Salt	"	2	492	5750	2	554	6557	2	583	7606	2	589	7605	2	478	5900
"	3	7·3	Fresh	"	2	329	2928	2	376	3600	2	392	3631	2	397	4040	2	282	4584
"	3	7·3	Salt	"	2	270	3157	2	348	3280	2	400	3[illegible]32	2	408	3872	2	335	3956
"	5	6·8	Fresh	"	2	184	1290	2	199	1548	—	—	—	2	176	1900	2	205	2725
"	5	6·8	Salt	"	2	173	1190	2	193	1256	2	196	2062	2	231	2125	2	220	1744
¼ River ¾ Beach	1	9·6	Fresh	"	2	570	5644	2	599	6607	2	517	6942	2	634	6700	2	655	6850
"	1	9·6	Salt	"	2	549	6218	2	563	6062	2	586	6841	2	526	6700	2	445	7875
"	2	9·6	Fresh	"	2	336	3870	2	373	4276	2	417	4595	2	411	5787	2	380	5160
"	2	9·1	Salt	"	2	305	3782	2	352	4075	2	370	3780	2	400	4830	2	362	5912
"	3	9·1	Fresh	"	2	216	2375	2	262	2697	2	273	3190	2	309	3125	2	261	3607
"	3	8·8	Salt	"	2	218	2453	2	248	2966	2	269	3025	2	277	2875	2	292	3060
"	5	9·1	Fresh	"	2	137	1124	2	151	1100	2	188	1540	2	213	1916	2	200	2070
"	5	8·8	Salt	"	2	131	989	2	150	1594	2	177	1816	2	196	1964	2	221	1935

quettes mixed with salt water were ahead of those mixed with fresh on short-time tests, but that the long-time tests nearly always showed the superior strength of the briquettes mixed with fresh water, and this was just as pronounced in the compression as in the tension tests. It will also be noticed that the deteriorating effect of salt water in gauging is the greatest on the richer mortars. The test

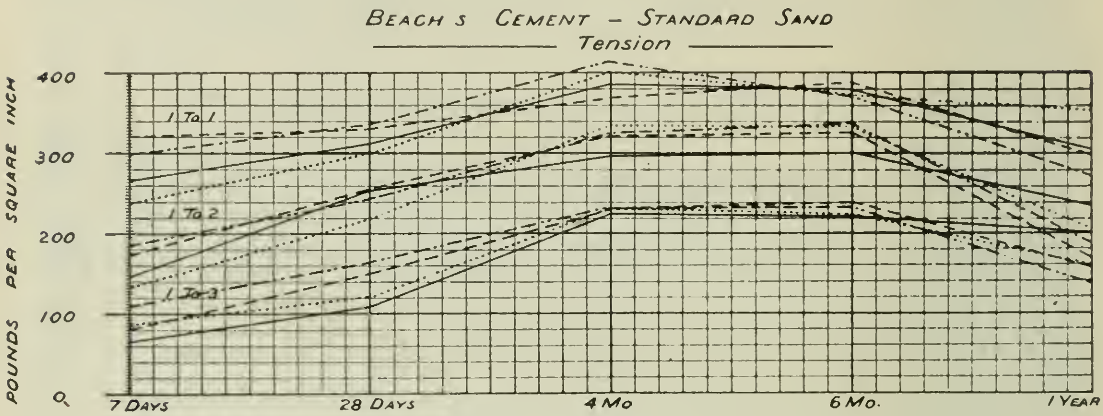

Diagram No. 5.

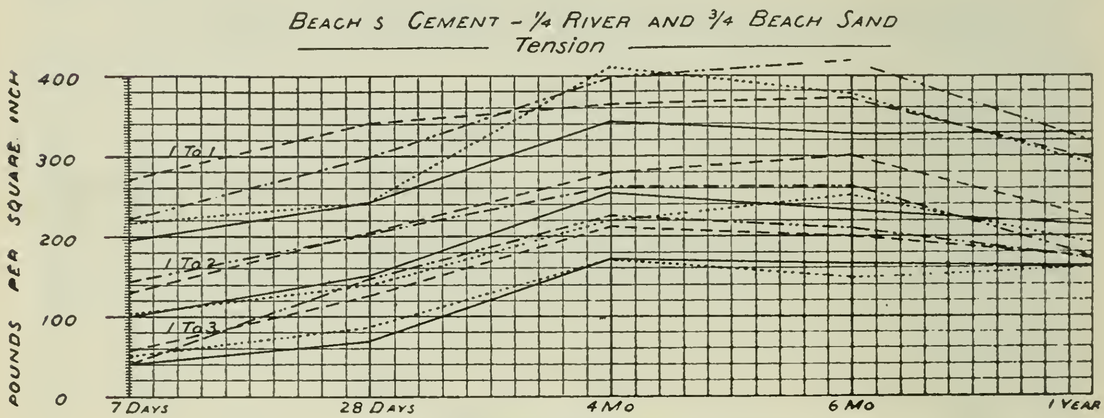

Diagram No. 6.

pieces that were immersed in salt water nearly always fell below the corresponding ones that were placed in fresh.

In a general way the same thing will be noticed in the case of the natural cement tests, Table No. 2 and Diagrams Nos. 5 to 8. The sample selected, however, seems to have been a poor one, as it shows less strength at one year's time than at six months. The decrease of the salt water briquettes is greater than the fresh, and therefore shows the

TABLE No. 2.—SHOWING RESULTS OF TESTS MADE FROM ONE SAMPLE OF NATURAL CEMENT TO DETERMINE THE EFFECT OF SALT WATER USED IN GAUGING AND FOR IMMERSION.

Sand.		Water.			7 Days.			28 Days.			4 Months.			6 Months.			1 Year.		
Kind.	Ratio to 1 of Cement.	Per Cent. to Dry Ingredients.	Gauging.	Immersion.	No. of Tests.	Tension.	Compression.	No. of Tests.	Tension.	Compression.	No. of Tests.	Tension.	Compression.	No. of Tests.	Tension.	Compression.	No. of Tests.	Tension	Compression.
Standard	1	11·1	Fresh	Fresh	1	266	2586	2	310	3577	2	385	4506	2	377	—	2	305	5505
"	1	11·1	Salt	"	2	237	3106	2	297	3910	2	400	4789	2	370	—	2	356	5460
"	2	9·3	Fresh	"	2	147	2223	2	250	2685	2	296	3712	2	298	—	2	235	4266
"	2	9·3	Salt	"	2	134	2105	2	218	2558	2	335	3519	2	332	—	2	207	4039
"	3	9·3	Fresh	"	2	65	1020	2	107	1887	2	223	2572	2	221	—	2	200	3236
"	3	9·3	Salt	"	2	87	—	2	120	1410	2	230	1961	2	238	—	2	173	2056
¼ River ¾ Beach	1	12·0	Fresh	"	1	198	2412	2	241	3261	2	342	3987	2	327	—	2	328	4036
"	1	12·0	Salt	"	2	217	2555	2	242	3380	2	409	4068	2	378	—	2	291	3405
"	2	10·9	Fresh	"	2	101	1346	2	148	1800	2	257	3112	2	232	—	2	210	4649
"	2	10·5	Salt	"	2	143	1047	2	201	1658	2	260	2138	2	263	—	2	175	2092
"	3	10·4	Fresh	"	2	41	—	2	68	1002	2	174	1619	2	166	—	2	162	2675
"	3	10·4	Salt	"	2	55	—	2	88	—	2	172	1535	1	150	—	2	160	1987
Standard	1	11·1	Fresh	Salt	2	320	3212	2	331	3634	2	369	3720	2	388	—	2	299	3525
"	1	11·1	Salt	"	2	298	3042	2	334	3750	2	414	3687	2	368	3212	4	275	3315
"	2	9·6	Fresh	"	2	177	2240	2	256	2317	2	322	2921	2	325	—	2	170	2939
"	2	10·4	Salt	"	2	188	2532	2	243	2700	2	325	2959	2	334	3112	2	191	2581
"	3	9·3	Fresh	"	2	92	1084	2	150	1440	2	228	1440	2	223	—	2	162	1940
"	3	9·3	Salt	"	2	110	1218	2	164	1455	2	232	1650	2	237	—	2	140	1804
¼ River ¾ Beach	1	11·8	Fresh	"	2	274	2691	2	341	3052	2	365	2700	2	376	4187	2	294	2701
"	1	12·0	Salt	"	2	223	2687	2	297	3068	2	397	2871	2	419	—	2	318	3270
"	2	10·4	Fresh	"	2	131	1312	2	207	1880	2	281	2268	2	301	2540	2	231	2617
"	2	10·5	Salt	"	2	143	1047	2	201	1658	2	260	2138	2	263	—	2	175	2093
"	3	10·1	Fresh	"	2	58	581	2	125	1061	2	210	1460	2	200	1834	2	187	1770
"	3	10·4	Salt	"	1	40	—	2	149	920	2	227	1552	2	216	—	2	175	1819

same results as in the other case. In the compression tests with this sample the results are better.

CONCLUSIONS.

These results would seem to justify the conclusion that salt water is injurious to cement mortar, and that the use of

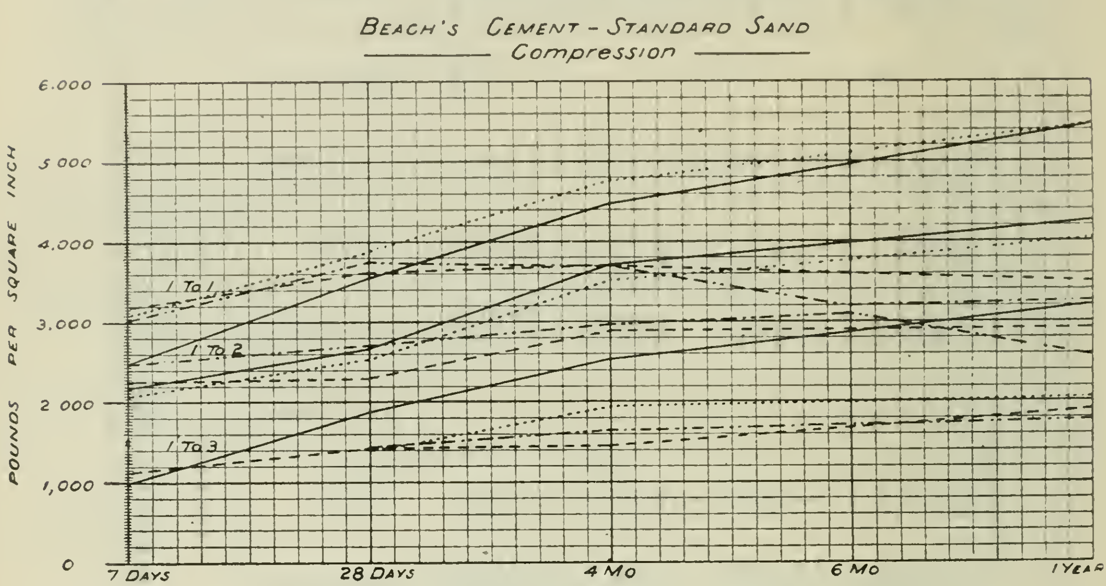

Diagram No. 7.

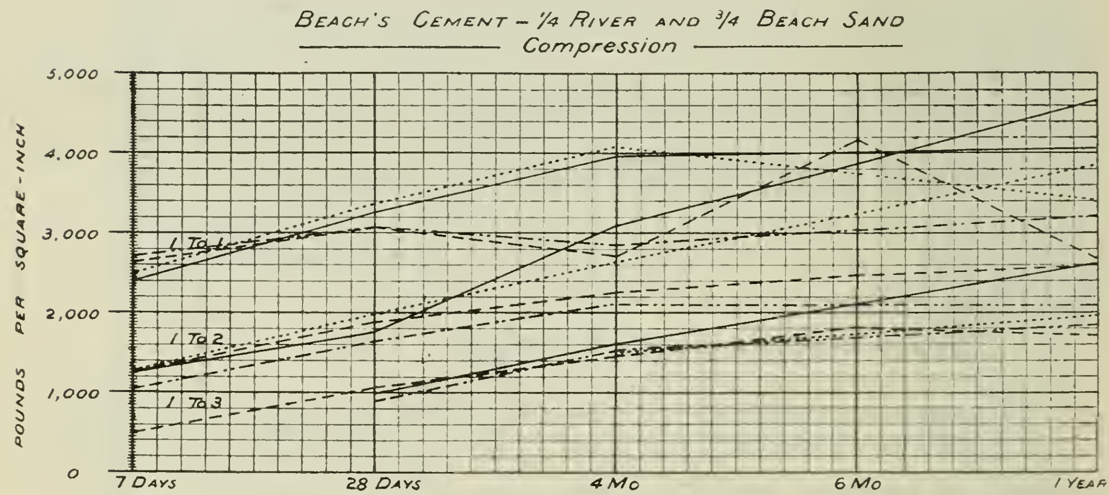

Diagram No. 8.

salt or sea water in gauging mortar is bad practice. The tests are not extended over a sufficient length of time to draw a decided conclusion as to the effect of sea water on engineering structures built of concrete, gauged with fresh

water, but they seem to point to a tendency to weaken them.

TABLE No. 3.—BRIQUETTES MADE OF ONE SAMPLE OF PORTLAND CEMENT AND BROKEN AT 11 MONTHS, TO TEST THE EFFECT OF SIZE OF SAND WHEN PERFECTLY RAMMED INTO MOULDS.
GRANITE SAND.

Sand.		Water, Per Cent. of.	Tension.				Compression.			
Size.	Ratio to 1 of Cement.		No. of Tests.	Highest.	Lowest.	Mean.	No. of Tests.	Highest.	Lowest.	Mean.
6–8	3	7·3	3	418	314	381	3	5325	4350	4675
8–12	3	7·3	4	392	314	359	4	4225	3520	3918
12–16	3	7·3	4	320	280	300	3	3300	2800	3100
16–20	3	7·7	4	412	316	350	4	3833	3312	3503
20–30	3	7·7	4	428	357	386	3	3200	2380	2833
30–100	3	8·3	4	371	282	340	2	3080	2725	2902
Passed 100	3	8·3	4	315	270	290	3	3400	3212	3333
6–8	1	8·3	4	544	460	493	4	7600	5975	7012
8–12	1	8·3	3	554	482	513	3	7825	6500	7041
12–16	1	8·3	4	610	540	571	4	7725	6612	7194
16–20	1	8·3	4	622	572	597	4	8075	6700	7240
20–30	1	8·8	4	680	584	618	4	7925	7425	7781
30–100	1	9·3	4	675	643	660	3	8175	7837	7903
Passed 100	1	9·9	4	535	498	518	4	6088	5825	5956

TABLE No. 4.—QUARTZ SAND.

Sand.		Water, Per Cent. of.	Tension.			
Size.	Ratio to 1 of Cement.		No. of Tests.	Highest.	Lowest.	Mean.
12–16	3	7·3	4	471	351	405
16–20	3	7·3	4	453	375	413
20–30	3	7·8	4	386	333	356
20–30	1	8·8	4	815	745	781

EFFECT OF SIZE OF SAND ON CEMENT MORTAR.

In the September number of the *Journal of the Franklin Institute*, 1896, was published an article on the effect

TABLE No. 5.—TRAP ROCK.

Sand.		Water, Per Cent. of.	Tension.				Compression.			
Size.	Ratio to 1 of Cement.		No. of Tests.	Highest.	Lowest.	Mean.	No. of Tests.	Highest.	Lowest.	Mean.
6–8	3	6·3	4	407	396	402	3	5025	4200	4700
8–12	3	6·3	4	461	261	349	4	4975	2750	3862
12–16	3	6·8	4	455	337	401	4	5275	3750	4494
20–30	3	6·8	4	407	290	369	4	4425	3025	3787
30–100	3	7·3	4	415	333	378	4	4500	3175	3725
Passed 100	3	8·3	4	365	282	321	4	4550	3575	4081
8–12	1	7·3	4	692	555	600	4	8325	6250	7106
12–16	1	7·3	4	730	565	621	4	8825	7675	8381
16–20	1	7·8	4	775	650	714	4	9500	8050	8962
20–30	1	8·0	2	671	632	651	2	10025	9775	9900
30–100	1	8·9	4	820	630	723	4	9725	7325	8675
Passed 100	1	13·0	4	837	640	747	4	8450	7800	8162

TABLE No. 6.—RIVER SAND.

Sand.		Water, Per Cent. of.	Tension.				Compression.			
Size.	Ratio to 1 of Cement.		No. of Tests.	Highest.	Lowest.	Mean.	No. of Tests.	Highest.	Lowest.	Mean.
6–8	3	6·3	4	393	257	318	4	5750	4050	4718
8–12	3	6·3	4	372	300	331	4	5575	5075	5331
12–16	3	6·3	4	327	234	282	4	5025	4350	4712
16–20	3	6·7	4	385	239	314	3	4400	3675	4125
20–30	3	7·3	4	373	279	313	4	5500	4350	4772
6–8	1	7·3	4	446	350	397	4	6800	5750	6387
8–12	1	8·3	4	494	437	476	4	8100	6950	7562
12–16	1	8·3	4	592	577	587	4	8750	6875	8106
16–20	1	8·3	4	705	564	615	4	8800	8325	8460
20–30	1	8·3	4	660	625	635	4	9137	7975	8846

TABLE No. 7.—TEST OF BRIQUETTES MADE OF ONE SAMPLE OF PORTLAND CEMENT, PROPORTION 1 : 3, AND BROKEN AFTER ONE YEAR'S TIME, TO DETERMINE THE EFFECT OF LETTING MORTAR STAND AFTER MIXING.

Kind of Sand.	Per Cent. of Water.	Made When Mixed.		Made 1 Hour After Mixing.		Made 2 Hours After Mixing.		Made 3 Hours After Mixing.		Made 4 Hours After Mixing.		Made 5 Hours After Mixing.		Made 6 Hours After Mixing.		Made 7 Hours After Mixing.		Made 8½ Hours After Mixing.	
		Tension.	Compression.	Tension.	Compression.	Tension.	Compression.	Tension.	Compression.	Tension.	Compression.	Tension.	Compression.	Tension.	Compression.	Tension.	Compression.	Tension.	Compression.
Beach .	14·	232	2350	248	2400	227	2487	211	2440	—	—	—	—	—	—	—	—	—	—
"	9·7	182	2056	181	1700	172	1553	176	1650	—	—	—	—	—	—	—	—	—	—
"	15·3	240	2400	230	2185	245	2523	227	2270	—	—	229	2306	—	—	226	2281	236	2260
River .	13·9	244	2775	233	2794	194	3031	—	—	240	2987	—	—	259	2715	235	2756	—	—

of the size of sand, in which it was clearly shown that coarse sand made the strongest mortar. In Tables Nos. 3 to 6 will be found another series of tests on the same subject, but in this case the briquettes were all made on a hammer machine after the method just described.

From these tests it will be seen that when perfectly rammed the size of the sand is not so important as with ordinary ramming. It is evident, however, that the size of the sand has some effect even with these briquettes, and the richer the mortar the less the effect of the size of the sand becomes. The large sand also shows to better effect in the compression tests than in the tension.

The superior strength of the rougher sands, like that obtained from breaking up trap rock, is, however, just as apparent with these perfectly rammed briquettes as it was with those made in the ordinary way. It would, therefore, be a safe conclusion that the condition of the surface of any sand is a more important factor in the strength of concrete than the size.

TIME OF SET.

As it is the prevailing opinion with many engineers that a cement mortar which has stood an hour or two has lost some of its strength, it is thought worth while to give here a set of tests made to determine the amount of lost strength of Portland cement mortar due to its standing after mixing and before using. Four large batches of mortar were mixed and briquettes made by hand from each pile at intervals ranging up to eight and one-half hours after mixing. These were all carefully marked and stored away as usual, and broken after one year. The results are shown in Table No. 7, from which it will be seen that the loss of strength after eight and one-half hours' standing is practically nothing.

In practical working with most Portland cement, if it becomes necessary for the mortar to stand for one-half of a day even, no injury will result, provided the precaution is taken to keep the mortar wet.

U. S. ENGINEER'S OFFICE,
SAVANNAH, GA., January 8, 1899.

On GASEOUS MIXTURES.

Two notes translated by B. F. Isherwood, U. S. Navy, from the *Comptes Rendus de l'Académie* of 1898, pages 218 and 338. The first note is by A. Leduc; the second note is by Paul Sacerdote.

FIRST NOTE. (BY LEDUC.)

Natural gases are too often likened to perfect gases. Thus, the law of gaseous mixtures is always stated in the following terms, which are in contradiction of the result of Berthollet's experiment* that they are supposed to express.

"*The pressure of a mixture of gases is equal to the sum of the pressures that each would have if it alone occupied the receptacle at the same temperature.*"

A priori, this law has but little probability. Referring to Berthollet's experiment of putting carbonic acid gas in the two receptacles, clearly their interdiffusion cannot produce the least change of pressure.

Let the CO_2 in one of these receptacles be replaced with Az_2O, which has sensibly the same critical constants, the same molecular mass and the same atomicity.

That the intermixture of the molecules of these two gases, physically identical apparently, will produce a variation of pressure cannot be conceived; nevertheless, the law above quoted predicts an increase of pressure of 2·6 millimeters. An experiment quickly shows that no such increase is produced.

I propose, therefore, to substitute for this law, which is always in default, the following law, which is rigorously exact in some cases and very closely approximate in general:

The volume occupied by a mixture of gases is equal to the sum of the volumes that would be occupied by the gases which compose it under the pressure and at the temperature of the mixture.

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* There results from both Regnault's experiments and my own that, if the law in question be exact, Berthollet should have confessed he had found an increase of pressure of 1·1 millimeters. I willingly admit that this increase had escaped his observation, but in that case he ought to have formulated the law *notwithstanding* instead of *because* of his experiment.

A long time ago investigations of the composition of atmospheric air led me to an equivalent announcement.

In a gaseous mixture each gas should be considered as under the total pressure, and not under the pressure it would have if it alone occupied the recipient.

(1) *Atmospheric Air.*—Thus, if the proportion of oxygen (x in volume) contained in air deprived of aqueous vapor, carbonic acid, etc., be sought by means of the densities of oxygen and of atmospheric nitrogen, there should be written

$$x \times 1{\cdot}10523 + (1 - x)\, 0{\cdot}97203 = 1,$$

which gives $x = 0{\cdot}21$ sensibly, and the proportion of oxygen in weight 0·2321, which latter I have found directly by experiment.

If, on the contrary, y be called the fraction of the total pressure due to the oxygen, there should be written, according to the classic law,

$$y \times 1{\cdot}10457 + (1 - y)\, 0{\cdot}97195 = 1,$$

whence $y = 0{\cdot}212$, and the proportion in weight $= 0{\cdot}2333$.

These results, together with those of my own experiments, as well as those obtained by Mr. Schloesing, Jr., show inadmissible discrepancies.

Although this single case is sufficient to warrant the rejection of the law in question, I have deemed that several other particular cases should also be submitted to experiment.

(2) *Protoxide of Nitrogen and Carbonic Acid Gas.*—Into my specific gravity receptacle I first introduced some protoxide of nitrogen at 0° under the pressure P, near 33 centimeters, and ascertained its weight. Then I added some pure carbonic acid gas under the pressure P_2, near 66 centimeters, and ascertained the increase of weight p.

Let V be the volume of the receptacle. Knowing the compressibility of the two gases, and the normal density of the second gas, I calculated the volume V' to which the Az_2O is reduced under the pressure P_2; then I calculated the weight p' of CO_2, which completes the filling of the receptacle $(V - V')$ under the pressure P_2.

The difference found ($p - p' = 1.3$ milligrams) is imputable to the different errors accumulated; it corresponds to a diminution of pressure of 0.2 millimeter, while the classic law requires an augmentation of 2.3 millimeters.

(3) *Carbonic and Sulphurous Anhydrides.*—The same operations and the same calculations being made, I have found experimentally

$$p = 3.0411 \text{ grams, and } p' = 3.0520 \text{ grams.}$$

If the law that I propose were not complicated by secondary phenomena, there could then enter into my receptacle 10.0 milligrams more of sulphurous gas.

I express this fact by saying that the gaseous mixture has been accompanied by an augmentation of pressure of 1.25 milligrams. The classic law requires an augmentation four times as great.

This augmentation of pressure can be attributed to the very different molecular weights of the mixed gases, these gases being far from being in corresponding states. Be that as it may, there can be no doubt of the experimental results.*

Application.—I have calculated anteriorly † the density of argon by employing my law of volumes—a method previously justified by the case of air—and by employing my densities of chemical nitrogen and of atmospheric nitrogen, as well as the proportion of *argon* in the latter according to Mr. Schloesing. I have found 19.80 instead of 19.94 found by Lord Rayleigh and Mr. Ramsay.

The difference is caused, in all probability, by the augmentation of pressure (or of volume) which ensues on the mixing of the nitrogen with the argon, similar to the case of SO_2 and CO_2; 10,000 volumes of atmospheric nitrogen are formed of 9,880 volumes of nitrogen and 119 volumes of argon. The molecules of the argon differ from those of the

* Mr. Sacerdote, who has very obligingly aided me in the making of these experiments, will repeat, with the greatest care, the experiment of Berthollet, which has the advantage of being direct, and his results will form the subject of a communication in the near future.

† *Comptes Rendus*, Vol. CXXIII, Page 805. 1896.

nitrogen not only by their mass, but also by their atomicity.

SECOND NOTE. (BY SACERDOTE.)

In a recent communication* Mr. Leduc has shown that the law of the mixture of gases, applied by means of the coëfficients of difference from the law of Mariotte, which we have precedingly measured,† leads to the following result:

Two gases under the same pressure being mixed, will, in consequence of that mixture, have an increase of pressure. For CO_2 and SO_2, primitively at the pressure of 76 centimeters of mercury, the increase of pressure should be more than 0·5 centimeter of mercury. This has been verified by an indirect method based on measurement by densities, but such a method is not sufficient for demonstrating the necessity of a new law of gaseous mixtures.

These experiments made by measurement by densities are capable of very great precision, but they require multiple conditions, among others a nearly absolute purity of the gases; further, they have the inconvenience of making the verification sought depend on a certain number of numerical constants for the gases.

Direct experiments seemed then to be necessary for solving the problem; and, with the aid of the kindly counsels of Mr. Leduc, I proposed to repeat the experiment of Berthollet, but making it with all the precision obtainable by our actual methods of measurement.

Apparatus.—Two glass receptacles, of 750 cubic centimeters each, are connected by a three-way cock of 6 millimeters diameter, so as to permit a rapid diffusion of the gases. The necks bend at a right angle, in order that they can, after the filling of one of the receptacles, isolate it completely. The apparatus was perfectly dried by heating it for several hours, during which a vacuum was made in it, and dry carbonic acid gas was allowed to enter it alternately.

Experiments.—The receptacle to be filled is placed in broken melting ice, and a vacuum is maintained in it for at

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* *Comptes Rendus*, January 17, 1898.

† *Comptes Rendus*, August 2, 1897.

least an hour, during which the dry gas enters it, bubble by bubble, passing over phosphoric anhydride. Communication between the receptacle and the atmosphere is then made for a few minutes, after which the receptacle is isolated, and, at the same instant, the atmospheric pressure is ascertained to the $\frac{1}{100}$ of a millimeter, by means of a good Regnault-Leduc barometer. Immediately afterwards, the other receptacle is proceeded with in the same manner; the two fillings being thus effected at intervals during a few hours, the pressures of the two gases are equal to within $\frac{1}{10}$ or $\frac{2}{10}$ of a millimeter, and as the volumes of the two receptacles are nearly equal, the mean of the two barometric heights observed (all corrections made) can be taken as the pressure of both fillings. The diffusion is allowed to proceed during several days, and is made more active by some variations of temperature; finally the pressure of the mixture is ascertained by connecting the receptacles with a Regnault manometer.

Care was taken to establish, *a priori*, a difference in the level of the mercury in the two branches of this manometer, corresponding to the difference between the barometric heights on the day of the filling and on the day of the measuring, and also corresponding to the variation of pressure produced by the mixing of the two gases, a variation approximately known by a preliminary experiment. In opening the cock of the two receptacles there was then observed only a very feeble movement of the mercury. The correction to be made to the pressure as read is very small, which is quite advantageous, as it is a little uncertain, because it requires a knowledge of the volumes of the communicating tubes.

RESULTS: 1ST, Az_2O AND CO_2.

Pressure of filling	759·40 millimeters.
Pressure of mixture	759·48 "

The very small augmentation of pressure (0·08 millimeter) can be attributed to experimental errors.

Note.—As the diffusing lasted only two days in this experiment, I assured myself by analyzing the gaseous mix-

ture in each of the two receptacles, that the mixing was nearly complete.

2D, SO_2 AND CO_2.

Pressure of CO_2 = 765·64 millimeters . . . . } mean, 765·69
Pressure of SO_2 = 765·73 millimeters . . . . }
After four days the pressure of the mixture was 766·90.
After seven days the pressure of the mixture was 767·05.

In this case there is distinctly observed an augmentation of pressure caused by the mixing, but its value (1·36 millimeters) is very inferior to what it should have been according to the old law of the mixture of gases. The difference in the results obtained in the two cases of the experiments can be attributed to the facts that CO_2 and Az_2O have the same molecular mass and are in corresponding states at 0° and under the atmospheric pressure, while such are not the same for CO_2 and SO_2.

To Résumé.—These results confirm those which have been obtained by the method of measuring by the densities;* and, like those, they show that the received law of gaseous mixtures should be abandoned where pressures intervene, and the law substituted which makes the volumes intervene.

THE WORK OF THE INTERNATIONAL ASSOCIATION FOR TESTING MATERIALS.

An address by PROF. MANSFIELD MERRIMAN, of Lehigh University, Chairman of the American Section of the Association, at the second annual meeting, held in Pittsburgh, Pa., August 15–16, 1899.

Prior to the year 1800 little was known of the properties of the materials of construction. Galileo had shown, in 1638, that the strength of a rectangular beam varied with the square of its depth ; Hooke, in 1678, had announced the law that the stretch of a spring was proportional to the stress upon it ; various authors had discussed the forms of beams of uniform strength, and Euler, in 1744, had enunciated his formula for the resistance of columns under compression. Theory was far in advance of practice, for experiments had been so few and so imperfect that the elastic limit was scarcely recognized.

* Mr. Leduc has found, by the method of densities, that the mixing of SO_2 and CO_2 is accompanied by an augmentation of pressure of 1·25 millimeters, but the pressure of the mixture was only 66 millimeters instead of 77 millimeters.

During the years from 1800 to 1850 great progress was made in the theory of elasticity, and a slow growth took place in knowledge of the properties of materials under stress. The introduction of railroads and the consequent necessity of providing a firm roadbed and safe bridge structures gave a powerful stimulus to the investigation of metals in order that ample security might be afforded with the greatest degree of economy. The methods of testing were, however, so imperfect that progress was slow, and, with the exception of the classic researches of Hodgskinson, the work of this period was mostly of value as a preparation for that of the future.

After 1850 large testing machines for special purposes began to be built, elongation and ductility began to be carefully studied, and soon after 1870 it was recognized by many manufacturers that physical tests of metals were imperatively necessary in order to secure uniformity of product. As these tests were multiplied and the records subjected to investigation, the knowledge was gained that the strength of a specimen depended upon its size and proportions and also upon the manner in which the load was applied. The term elastic limit assumed a new significance when it became recognized that it could be defined and measured in different ways. In short, it was found that tests of materials must be made in a similar manner in order to render the results comparable. This idea, although long recognized, has proved a difficult one to realize. It has been discussed by many engineering societies, some of which have attempted to formulate methods. Finally, the International Association for Testing Materials was formed in order to study the whole subject and endeavor to arrive at conclusions that should be authoritative.

In 1882, through the influence of John Bauschinger, a number of German experimentors met at Munich and discussed the question as to how uniformity in the methods of testing materials could be promoted. As a result of this meeting, formal conferences were held at Dresden in 1884, at Berlin in 1886, at Munich in 1888 and at Vienna in 1893, delegates from other European countries being often present. The reports of the proceedings of these conferences attracted wide attention, and the great value and importance of the discussions became universally recognized in engineering circles. In short, the movement assumed an international character.

In 1890, as a result of the international congresses of engineering held at Paris in the preceding year, the French government appointed a commission to formulate standard methods for testing the materials of construction. Its report, published in 1894, in four large volumes, is one of the most valuable contributions to the subject, but from the first it was recognized that ultimate conclusions could not be determined by a commission of one nationality, and accordingly, since 1895, the French government has given hearty support to the work of the International Association.

In 1895, as a result of the four preceding conferences, the fifth conference met at Zurich, all European countries, except Turkey, being represented. The United States Government was represented by an army officer and the American Society of Mechanical Engineers by a delegate. At this congress the International Association for Testing Materials was formally organized, its object being, as stated in its statutes, "the development and unification of standard methods of testing for the determination of the properties of the

materials of construction and of other materials, and also the perfection of apparatus for that purpose." This meeting at Zurich hence assumed an importance far greater than any preceding conference, and it may be called the first congress of the International Association.

At the Vienna Convention of 1893 there had been appointed twenty committees on technical subjects, and reports from many of these were presented at the Zurich Congress of 1895. These reports were published in the French and German languages in the official organ of the Association, called *Baumaterialienkunde*, the first number of which appeared in July, 1896. The work of some of these committees was continued, other subjects were proposed for future consideration, and a council was organized to transact the business of the International Association in the intervals between the congresses.

In 1897 the second congress of the International Association was held at Stockholm, there being present 361 members, representing eighteen countries. The United States Government was represented by an army officer and a navy officer, and the American Society of Mechanical Engineers by a delegate. The congress continued in session for three days, reports of committees were presented, papers read and discussed, and plans outlined for the future work. It was resolved that the next congress should be held in Paris in the summer of 1900, and the council was authorized to appoint technical committees to make reports at that time on special problems relating to the objects of the Association.

At a meeting of the International Council held early in 1898 appointments were made of chairmen of nineteen committees on technical problems, and the number of members on each committee from each country was assigned. It was also recommended, in order to expedite the appointment and work of these committees, that the members in each country should meet and form a national section of the International Association. In compliance with this recommendation, a number of the American members met on June 15, 1898, and organized an American Section, whose first annual meeting was held at Philadelphia on August 27, 1898, and whose second annual meeting I now have the honor to address.

The membership of the International Association numbered 493 in 1895, 953 in 1896, 1,169 in 1897, 1,488 in 1898, and is now probably about 2,000. Germany takes the lead in regard to number of members, it having 387 in 1898, while Russia had 315, Austria 158, England 83, Switzerland 83, United States 68, Sweden 68, France 66, Holland 48, Norway 42, Denmark 39, Spain 36, Italy 35, and 60 from nine other countries. With regard to the American membership, it may be noted that it numbered 6 in 1895, 25 in 1896, 60 in 1897, 68 in 1898 prior to the organization of the American Section, 106 in February, 1899, and that it is now nearly or quite 125.

There are two peculiarities regarding membership in this Association that deserve notice. First, there is no nomination or election of members, but any person desiring to be a member may do so on signing a statement that he assumes membership and will be governed by the laws of the Association ; in so doing he further assumes the obligation, stated in Article V of the statutes, that he will advance its interests to the best of his ability. Membership is hence a voluntary act assumed by an individual in order to promote the

knowledge of the properties of materials and to endeavor to secure uniformity in methods of testing them. Withdrawal from membership may be made at any time by mere announcement to the proper officer of the Association.

The second noteworthy feature regarding membership is that it may be assumed by a corporation or society as well as by a person. For example, in the list of members of the American Section, published in February last, will be found the Franklin Institute, the American Society of Mechanical Engineers, the American Foundrymen's Association and five local engineering clubs, as also several steel companies, engineering journals and firms engaged in inspecting and testing. In Europe this feature is carried much further, the membership of the German Section including the bureau of public works of several cities, provinces and States, the police bureau of Berlin, the Prussian War Department and the boards of direction of numerous railroads, as also a large number of manufacturing corporations and engineering societies. Under this arrangement it is possible for a corporation to exert a greater influence than through the indirect individual membership of its president or superintendent, both manufacturers and consumers can make their wishes more directly known, and thus differences in regard to methods of inspection and testing can be more quickly harmonized than under the usual plan of strict individual membership. However, fully three-fourths of the total members are individuals, and these include engineers in all branches, architects, chemists, professors of mechanics and engineering, and superintendents and foremen of works.

At the Zurich Congress the dues of members were fixed at $1 per year, and while no change was made at the Stockholm Congress, the Council recommended early in 1898, in view of the heavy expenses, that each member should pay $1.50 per year. Accordingly, at the first annual meeting of this Section, when our present by-laws were adopted, the provision was inserted that each member should pay $2.50 per year, of which $1.50 should be transmitted to the International Association and the remainder be used to defray the expenses of the American Section. This by-law went into effect on January 1, 1899, and accordingly no dues were collected by this Section for the year 1898, the $1.50 payable for that year being forwarded to the International Council directly by each member or through the American member of that Council. During the present year dues have been paid directly to our Secretary, and his report, together with that of our Treasurer, will be laid before this meeting.

The dues of $1.50 per year per member transmitted to the International Council are used by it in issuing its publications and in assisting its committees in defraying a part of the expenses of their special investigations. In addition to this income, a number of societies and bureaus have agreed to make extra annual contributions, the Prussian War Department heading the list with $125, and twenty-one others giving smaller sums, so that for the year 1898 the amount derived from these sources was about $400. Although official information is not at hand, it is safe to say that the total income of the International Association for the year 1898 did not exceed $2,000, which is certainly a small sum with which to issue its publications and carry on the work of twenty-one committees.

The International Association has issued yearly since 1895 a list of members, and also abstracts of the proceedings of the congresses of 1895 and 1897.

These, together with a few circulars of information, constitute all the publications that it has been able to furnish free to its members. The detailed proceedings of the congresses have been printed in the journal *Baumaterialienkunde*, published in the French and German languages, at Stuttgart, which has been furnished to members at $2.50 per year. the regular subscription price being $3.50. It will be seen, therefore, that an American member who desires to be fully informed regarding the work of the Association must necessarily subscribe to this journal, and by so doing his dues become really $5 per year. It should further be stated that arrangements will probably be made so that the official announcements of the International Council and the proceedings of future congresses will be printed in this journal in the English language, as well as in German and French.

The American Section, as already stated, had no income during 1898, and the report of our Treasurer shows that during the present year the amount available for expenses has been about $120. On February 18th a pamphlet of twenty-six pages was issued, containing a list of officers of the International Association and its committees and a list of the American members, together with the statutes, by-laws and some historical information. In April a bulletin was issued giving abstracts of the proceedings of the first annual meeting and of the meetings of the Executive Committee, and in July a second bulletin was issued containing the preliminary program for this meeting. It is hoped that the condition of our treasury may permit these bulletins to be continued, and that one may be issued containing the proceedings of this meeting.

The technical questions proposed for discussion at the Paris Congress of 1900 are nineteen in number. The organization of the international committees which are to consider these topics is now complete, and preliminary reports from the American members of several of them are to be presented and discussed at this meeting. Probably the most important of these subjects is that of standard international specifications for testing and inspecting iron and steel ; this committee originally consisted of about forty members, of which five were assigned to this country, but under authority to increase its numbers the American sub-committee has been enlarged to twenty-one, has held several meetings, collected specifications and will present a preliminary report of much interest. It is also expected that the American members of five other international committees on iron and steel will report progress in their organization and work. As the national sub-committees are now in full correspondence with the international chairmen, it is expected that the final reports, which are to be presented for discussion at the Paris Congress, will prove of great interest and value.

Of the nineteen problems to be considered by the nineteen International Committees, six are on iron and steel ; one on stone and slate ; eight on cements and mortars ; one on tile pipe ; one on paints ; one on lubricants, and one on the dry rot of wood. The fact that there are eight committees on cements and mortars and only six on iron and steel may seem abnormal, but it should be remembered that in the testing of hydraulic cement the personal equation of the observer enters to a far greater degree than in the case of metals, and that its rapidly increasing use demands the immediate perfection of methods which will render comparable the work of differ-

ent laboratories. At the session to-morrow morning preliminary reports from some of our sub-committees on these questions will be presented.

While the main object of the Association is to establish standard rules for testing, it is recognized that this cannot be done until a thorough knowledge is obtained of the properties of materials under varying conditions. Accordingly, the work of some of the committees is to collect and digest the information now on record, or to make scientific investigations that will render present knowledge more complete and definite. Thus, there is a committee on the properties of steel at abnormally low temperatures, one on the relation of the chemical composition of stone to its weathering qualities, one to digest the work of previous conferences and conventions on the adhesion of hydraulic cement, one on the causes of the abnormal behavior of cements as to time of setting, and one on the protection of wood against the action of dry rot. Some of these subjects have already been discussed at the congresses of Zurich and Stockholm, and accordingly the reports to be presented to the Paris Congress should contain positive additions to present knowledge.

At the annual meeting of this section, held last year, the desire was expressed to discuss the subject of impact tests, and a special committee was appointed whose report will be presented at this meeting. Later, other members requested that other problems should be taken up by the section, and accordingly three other American committees have been organized on special problems connected with the manufacture of iron and steel. While these committees have no connection with the international ones, it is believed that their work will add to the interest of our annual meetings, and further the general objects of the Association.

There are advantages and disadvantages in doing technical work by committees. One advantage accrues through the harmonization of the different views held by individuals, whereby non-essentials are rejected and only fundamental methods retained. One of the disadvantages is that this process of harmonizing views takes time, causing reports to be long delayed, particularly with international committees. Some technical societies appoint committees with great reluctance, fearing that their reports may be regarded as official action. In the case of our international organization, no such fear is felt, and the report of a committee is to be considered from the same point of view as the paper of an individual member. Through the formation of the national sections, the work of the international committees can certainly be made more valuable and effective than ever before, for each national subcommittee, after having eliminated disagreements of its individual members, can work as a body to impress its views upon the other national sub-committees. In many cases an international agreement may be found difficult to make, but if made after such full discussion it will be sure to be authoritative and valuable.

The subject of the chemical analysis of iron and steel has been discussed in previous conferences and congresses, and at the Stockholm meeting of 1897 it was formally resolved to establish an international sidero-chemical laboratory at Zurich. It was stated that fifteen smelting companies and iron manufacturers had pledged themselves to contribute $3,500 per year for this purpose, and that the Polytechnicum at Zurich had offered the use of four well-equipped rooms. It was, accordingly, determined to open the laboratory in

1898, and an international commission was appointed to take charge of it and raise further funds for its maintenance. I am unable to state how fully this has been carried out, as no published accounts of its work have appeared. It it, however, to be doubted whether the establishment of chemical and physical laboratories falls properly within the scope of the objects of the Association. If sufficient funds could be raised so that men of different nationalities might meet at such a laboratory to actually make analyses and tests, each criticising the others, while at the same time learning from them, then undoubtedly effective work would be done in harmonizing differences and perfecting standard methods. It is to be hoped, if the establishment of the sidero-chemical laboratory at Zurich proves to be successful, that it may tend to further this method of research. It is however, the opinion of many members that results as good, if not better, would be secured by arranging systematic schemes of investigation and distributing the actual work of analysis or testing among the laboratories of different countries.

A brief history of the organization and work of the International Association for Testing Materials, and of that of its American Section, has now been given. The great interest taken in the movement in so many countries is an index of the necessity felt in all branches of the engineering profession for the introduction of uniform methods of testing and inspecting the materials of construction. This work is one that must occupy many years, and which in a certain sense can never be finished, for constant progress will be made in our knowledge of the properties of materials. In order to carry it on with success it is apparent that more money will be needed than the small amount now raised from the annual dues of members. In Europe the importance of the work of the Association is forcibly attested by the fact that engineering societies, bureaus of public works, iron and cement manufacturers, and railroads assist it by extra annual contributions, and it is to be hoped that the influence of this Section may be sufficient to cause similar substantial gifts to flow into its treasury from American corporations A proposition to establish a fund for research and publication will be introduced for discussion at this meeting.

Since the above was written a circular of the International Council has been received, containing the information that probably arrangements cannot be made for holding the congress of the Association at Paris in 1900. It appears that the authorities of the Paris Exposition have the right to control the organization of all congresses held in that city in that year, and that they have announced one to be held on the subject of materials, and appointed officers to conduct the same. The subject will be discussed at this annual meeting, and expressions of opinion are desired as to whether it is best to abandon our congress of 1900, in order to co-operate with the one announced by the authorities of the Paris Exposition, or to hold it at London during the week preceding.

In conclusion, it is with pleasure that I congratulate the American Section upon its activity and the Association itself upon the bright prospects before it. The undertaking inaugurated by Bauschinger and his associates bore good fruit at the conventions of 1884, 1886, 1888 and 1893, and prepared the way for the Zurich meeting of 1895, which was at the same time the fifth convention and the first congress. At the Stockholm Congress of 1897 the true inter-

national work was begun, and the problems there proposed are now the subject of careful study in all parts of the earth. Let us hope that the reports to be presented at the future congresses will be such as to add to the present stock of knowledge, prove advantageous to both producers and consumers, and assist all engineers in economically using the materials and forces of nature for the benefit of man.

NOTES AND COMMENTS.

AMMONIA AS A FIRE-EXTINGUISHER.

The editor of the *National Druggist* gives some highly interesting information respecting the fire-extinguishing qualities of aqua ammoniæ, which are worthy of attention, as the following statements will indicate:

"In one instance, where fire had originated, probably from spontaneous combustion, in a pile containing several tons of cotton-seed, and the interior of which was almost a solid body of live coal, a half gallon of ammonia completely smothered the fire. In another, which occurred in Savenay, France, the vapors of a tank containing 50 gallons of gasoline caught fire in the linen room of a laundry. The room was instantly a mass of living flames, but a gallon and a half of ammonia water thrown into it completely and almost immediately extinguished the fire. The ammonia was in a glass demijohn in an apothecary's shop next door to the laundry, and was thrown into the room by the druggist as an experiment. To use his own words in reporting the circumstance * * * 'The effect was instantaneous, torrents of black smoke rolled upward in place of flames, and in a moment every trace of fire was gone. So completely was the fire extinguished, that workmen were enabled to enter the room almost immediately, where they found the iron tank of gasoline intact.'"

A SIMPLE SUGGESTION FOR REMOVING BOILER SCALE.

The following simple suggestion for the removal of scale from boilers is recorded in the Bulletin of the Society for the Encouragement of National Industry, in Paris. To this the interesting observation is reported that boiler scale is rendered quite loose, and is for the most part washed away on emptying out the water, if the boiler is allowed to cool off very slowly after being taken out of use. This graded cooling occupies considerable time—more or less, according to the size of the boiler; generally, however, from eight to ten days. The scale state remaining adherent to the shell, it is added, can be washed away by a strong jet of water.

It will occur at once to the mechanical reader that, however effective the process may be, it will scarcely come into general favor for the reason that it necessitates putting the boiler out of service for too long a time; but in cases where this circumstance happens to be not objectionable, it might be worthy of a trial. It is added, in relation to the subject, that this method will be found specially convenient for boilers with narrow pipes or parts that are difficult of access.

Franklin Institute.

[*Proceedings of the stated meeting held Wednesday, September 20, 1899.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, September 20, 1899.

MR. JOHN BIRKINBINE, President, in the chair.

Present, 82 members and visitors.

Additions to membership since last report, 71.

The Actuary reported that the Managers of the National Export Exposition have requested the Franklin Institute to undertake the duty of making the awards at the Exposition, under the rules of the Institute, and that the Board has accepted the responsibility.

The Secretary read the following extract from the minutes of the stated meeting of the Library Committee, held September 11, 1899, viz.:

"The Committee directed an entry to be made upon its minutes expressing the profound regret of the members at the death of William P. Tatham, for many years identified with the Committee as a member and as Chairman, and whose activity and zeal in furthering the interests of the Library are held in grateful remembrance."

The following amendments to the by-laws of the Institute were offered, and, in accordance with the usual course of procedure, were ordered to publication, viz.:

Resolved, That paragraph 1 of Section 8 of Article III be amended by striking out the word "fifty" and inserting in place thereof the words "twenty-five," so that the paragraph, as amended, shall read:

"Non-resident members shall be those who reside permanently at a distance not less than twenty-five miles from Philadelphia."

Resolved, That Section 2 of Article IV be amended by adding thereto the words:

"A non-resident life membership (not transferable) may be acquired by the payment of $40.00 in any one year," so that the section, as amended, shall read:

"Holders of second-class stock, and contributing members enrolled as non-resident members, shall pay, upon election to membership, an entrance fee of $5.00 and an annual fee of $2.00. A non-resident life membership (not transferable) may be acquired by the payment of $40.00 in any one year."

The President gave a brief account of the co-operative work of the Institute in connection with the National Export Exposition, and called upon Mr. Henry Howson, Chairman of the Committee on Exhibitions, for the details. Mr. Howson made a report, of which an abstract is given below, viz.:

ABSTRACT OF REPORT OF THE COMMITTEE ON EXHIBITIONS.

Your Committee presents the following report of its work and of those associated with it, in preparing for the National Export Exposition of 1899.

The Executive Committee of the National Export Exposition consists of representatives of the Exposition Association, an organization duly chartered to carry on an exposition, the Commercial Museums and the Franklin Institute. This Executive Committee was divided into numerous sub-committees, who were to do the actual work of preparing for the Exposition. These sub-committees are as follows :

Grounds and Buildings ; Rules and Regulations ; Amusements, Attractions and Concessions ; Law ; Publicity ; Finance, Admittance and Insurance ; Classification and Space. * * * *

Owing to the fact that the majority of the members of the Executive Committee were active business men, it was deemed advisable to have as few meetings as possible for the proper conduct of the work. The detail work was done by the several sub-committees above noted.

The reports of the sub-committees were made direct to the Board of Directors of the Exposition as the responsible head.

In all organizations of this kind some few members do the actual work, and the members representing the Franklin Institute have attended faithfully the meetings of the several sub-committees ; in fact, we have always had a fair representation and oftentimes a majority of the members present, and the Board of Directors has invariably approved the work. We are happy to say the Exposition opened, on the 14th of September, under the most favorable conditions.

When we take into consideration the fact that in the spring of this year the contract for the buildings was not let, arrangements for space were not made, even the plans for the buildings were not drawn, and some of the ground not yet acquired, it was remarkable that the buildings were finished for the reception of goods before the opening day of the Exposition, and that the grounds were so near completion on the opening day ; all this work being done under the most unfavorable circumstances, owing to the fact that the prices of materials were increasing by daily jumps, so that in making contracts we would have to make them immediately, otherwise we could not hold the contractors. In some cases iron was not available and wood had to be substituted, and when we substituted wood in the construction of the buildings, this was almost impossible to obtain without considerable delay ; and yet, with all these difficulties in the way, the buildings were constructed on time, and if it had not been for the usual tardiness of exhibitors, the Exposition would have been much further advanced on the opening day than any important exposition held since the Centennial. * * * *

The buildings are three in number. The main building is about 1,000 feet long by 400 feet wide, and has a total area of 200,000 square feet. It is constructed of three permanent pavilions, which will eventually form the wings of the permanent buildings of the Commercial Museums, the south and central wings being connected by the main exhibition hall, which contains some of the finest exhibits that have ever been shown at an exposition. The three permanent pavilions and this exhibition hall were constructed by Mr. Rorke, and they were completed in time according to contract. The central pavilion is connected to the north pavilion by the auditorium, which is capable of seating 6,000 people, and on each side of the auditorium are wide exposition halls. This auditorium building was constructed by Mr. Seeds, and was com-

pleted about two weeks ahead of time, and this is certainly remarkable when we consider the times and the conditions under which the contractor had to work.

The Vehicle and Implement Building is 450 feet long and 160 feet wide, and the Transportation Building is 450 feet long by 75 feet wide. These two buildings were constructed by Messrs. Pennock Brothers, and they completed their work on time.

The exhibition space includes the entire lower floor of the main building, with the exception of the auditorium, the entire floor of the Vehicle and Implement Building and the entire Transportation Building.

The second floor of the central pavilion is devoted to an exhibit by the Commercial Museums, of goods manufactured in other countries for the export trade, while the second floor of the south wing is devoted to the executive offices of the Exposition Association, and the second floor of the north wing to the Convention Hall, a first-class restaurant, the Franklin Institute reception rooms and sundry committee rooms. * * * *

THE SEVENTY-FIFTH ANNIVERSARY.

In reference to the seventy-fifth anniversary, elaborate preparations have been made to celebrate the occasion during the first week of October, and it is hoped that the members of the Institute will aid the Committee by their support and attendance.

A program has been arranged giving each Section of the Institute one evening, and there will be a general Institute meeting on the closing night, Saturday, October 7th, at which Professor Thurston and Rear-Admiral Melville, Engineer-in-Chief of the U. S. Navy, will make the addresses.

Invitations are now being engraved and programs printed. These invitations and programs, together with the passes, will be received by each member within a week.

A Franklin Institute reception room has been provided on the second floor of the north pavilion of the Exposition Building, directly over the main entrance. An employé will be in attendance at this reception room during the Exposition, and it will be used as a reading and waiting room for the members and their friends. We hope that the members will avail themselves of this room.

The details, in reference to the awards, have not yet been worked out, but this matter has been placed entirely in the hands of the Franklin Institute. * * * *

HENRY HOWSON,
Chairman Committee on Exhibitions.

PHILADELPHIA, September 20, 1899.

The Secretary called attention to the notable circumstance that the Honor able Frederick Fraley, one of Philadelphia's oldest and most distinguished citizens, was the sole survivor of the founders of the Institute, and urged the propriety of taking special action in connection therewith; whereupon the following resolution was adopted unanimously:

"The members of the Franklin Institute, in stated meeting assembled, and engaged in the consideration of plans for the celebration of the Seventy-fifth

Anniversary of the Society, by unanimous vote have instructed their President and Secretary, in their behalf, to convey to the Honorable Frederick Fraley, their cordial felicitations upon the unique circumstance that he, of all his colleagues, who attended the historic meeting in the County Court House, Sixth and Chestnut Streets, on February 5, 1824, to inaugurate the Franklin Institute, still survives, and to express their earnest hope and expectation that he will be able to honor the occasion of the closing ceremonies on 'Institute Day,' Saturday, October 7th, or any of the ceremonies of Institute week, in the Convention Hall of the National Export Exposition, with his presence and participation."

Mr. Joseph N. Goldbacher, of New York, gave a description of the Bournonville Acetylene Gas Machine, and exhibited the apparatus in operation.

Mr. James Hough, of New York, gave a description and exhibited the operation of a series of improved draughtsman's tables.

Adjourned. WM. H. WAHL, *Secretary.*

PROVISIONAL PROGRAM OF THE SEVENTY-FIFTH ANNIVERSARY OF THE FRANKLIN INSTITUTE.

The celebration of the Seventy-fifth Anniversary of the Institute should properly have taken place on February 5, 1899. In view, however, of the circumstance that the Institute would probably participate in conducting the National Export Exposition in the autumn, it was decided by the Board of Managers to postpone the event and arrange to have the celebration take place during the exhibition, as part of the numerous public functions to be held in connection therewith.

In accordance with this decision, it has been arranged to hold in the Convention Hall of the Exposition, during the week beginning Monday, October 2d, and ending Saturday, October 7th, a series of special anniversary meetings under the direction of the several Sections of the Institute, to follow one another on successive evenings, and to be concluded by a special meeting of the Institute. At these meetings it has been arranged that addresses appropriate to the occasion shall be delivered by distinguished invited guests and members of the Institute. The series of meetings and addresses thus far tentatively arranged is as follows (*subject to change*):

MONDAY, OCTOBER 2D, 8 P.M. CHEMICAL SECTION.

Dr. Joseph W. Richards, Bethlehem, Pa., President of the Section. "Introductory Address."

Prof. Harvey W. Wiley, Washington, D. C. "The Progress of Chemistry as Applied to the Arts."

Dr. Charles F. Himes, Carlisle, Pa. "Photography and Microscopy in their Applications to the Arts" (Photographic and Microscopic Branch).

TUESDAY, OCTOBER 3D, 8 P.M. ELECTRICAL SECTION.

Dr. Edwin J. Houston, Philadelphia, Pa. "The Seventy-fifth Anniversary of the Franklin Institute from an Electrical Standpoint."

Mr. Ralph W. Pope, New York. "The Influence of such Societies as the Franklin Institute and the American Institute of Electrical Engineers in Promoting the Progress of the Electrical Arts."

Prof. F. B. Crocker, New York. "The Commercial Aspects of American Electrical Industries."

WEDNESDAY, OCTOBER 4TH, 8 P.M. MINING AND METALLURGICAL SECTION.

Mr. James Christie, Philadelphia, Pa., President of the Section. "Introductory Address."

Mr. Chas. Kirchhoff, New York. "Three-quarters of a Century's Progress in Mining and Metallurgy."

Mr. John Fritz, Bethlehem, Pa. "The Development of Iron Manufacture in the Past Seventy-five Years."

THURSDAY, OCTOBER 5TH, 8 P.M. MECHANICAL AND ENGINEERING SECTION.

Mr. Wilfred Lewis, Philadelphia, Pa., President of the Section. "Introductory Address."

Dr. Coleman Sellers, Philadelphia, Pa. "The Progress of the Mechanical Arts in Three-quarters of a Century."

FRIDAY, OCTOBER 6TH, 8 P.M. PHYSICAL AND ASTRONOMICAL SECTION.

Dr. A. E. Kennelly, Philadelphia, Pa., President of the Section. "Introductory Address."

Dr. T. C. Mendenhall, Worcester, Mass. "The Progress of Physics and Astronomy."

SATURDAY, OCTOBER 7TH, 8 P.M. "INSTITUTE DAY."

Mr. John Birkinbine, Philadelphia, Pa., President of the Institute. "Introductory Address."

Dr. Robert H. Thurston, Ithaca, N. Y. "The Evolution of Technical Education and its Progress during the Past Seventy-five Years."

Rear-Admiral Geo. W. Melville, Engineer-in-Chief, U. S. N. "The Modern Warship as Combining in Itself the Highest Results of Skill, Ingenuity and Scientific Knowledge."

[The presence and participation, on this occasion, of Hon. Frederick Fraley, the sole surviving foundation member of the Institute, are earnestly hoped for.]

The management of the National Export Exposition has extended to the members of the Institute and its invited guests the privilege of free admission during "Institute Week" (October 2d to October 7th, inclusive), and passes will be mailed to members in good standing prior to October 1st.

JOURNAL

OF THE

FRANKLIN INSTITUTE

OF THE STATE OF PENNSYLVANIA,

FOR THE PROMOTION OF THE MECHANIC ARTS.

VOL. CXLVIII, No. 5. 74TH YEAR. NOVEMBER, 1899

CHEMICAL SECTION.

INTRODUCTORY ADDRESS.

BY DR. JOSEPH W. RICHARDS,
President of the Section.

[Commemorative Meeting held in Convention Hall, National Export Exposition, Monday, October 2d, on the Occasion of the Celebration of the Seventy-fifth Anniversary of the Franklin Institute.]

The Chemical Section of the Institute, being the oldest of its sections, has been charged with the pleasant duty of inaugurating the proceedings of this commemorative week.

Chemical science has always been prominently represented among the Institute's membership. The organizer of the Institute, Samuel V. Merrick, was himself a practical mechanician, but he had as his co-worker William H. Keating, Professor of Chemistry at the University of Pennsylvania, and these two sent out together the first call for a preliminary meeting. Thus mechanics and chemistry conjointly presided at the birth of the Institute, fittingly typical of its future sphere of activity.

As soon as the Institute was officially organized, Professor Keating was appointed its professor of chemistry, thus from the start recognizing and confirming the prominent relation which chemical science was meant to sustain towards the work and objects of the Institute.

The duties of the Institute's professor of chemistry appear to have been the delivery of a graded course of lectures to students and apprentices, the arranging of lectures by prominent specialists in chemistry, the editing of chemical communications offered to the Institute for reading and publication, giving criticism and expert advice to the Committee on Inventions and Discoveries, and acting as conservator of the chemical apparatus and equipment of the Institute. With the establishment of the Philadelphia High School, and the general development of the higher educational facilities in and around this city, the graded course of lectures became superfluous, and, on the organization later of the Chemical Section, the functions of the professor of chemistry have been shifted to it and its various committees.

In 1881, the chemical work of the Institute was of sufficient importance to warrant the formation of a distinct section for the discussion of the particular problems of pure and applied chemistry. It was true then, as now, that at the general meetings of the Institute only questions of general scientific interest can be brought forward, while problems of interest only to professional chemists, or capable of being understood and discussed only by such, were necessarily excluded from the program. The chief advantage of the formation of the section was that it enabled the chemists to come together at their own meetings, to discuss without the distractions of a general assemblage the higher problems of chemical science and industry. The result was the immediate enlargement of the sphere of the Institute's activity.

This principle of the subdivision of the Institute's work has been so fruitful of results that the example thus set has been followed by the formation of no less than four other sections and one sub-section. Specialization is to art and

science what division of labor is to industry; it is the modern method of setting every one to work and reaching large results. The creation of each new section has been a distinct gain to the Institute, stimulating individual effort in the directions thus specialized and reacting on the rest of the membership by the general increase of interest in the Institute's work.

This year has seen the principle extended to a still greater degree, the organization of the Photographic and Microscopic Branch of our Section having been such a success as to amply justify its formation. As you may see from the program, the latter half of this evening's proceedings are in their hands. The creation of new sections as rapidly as circumstances will justify their formation is therefore *the* characteristic of the Institute's present policy, and the ideal condition of the Institute's plan will only be attained when every prominent branch of science, art and industry has its appropriate section, and every member of the Institute, whatever his specialty, can be thus enrolled among congenial co-workers. The perfected plan will result in a republic of free and independent sections under the general presidency of the parent Institute.

Previous to 1881, nearly a hundred original communications on chemical subjects had appeared in the *Journal* of the Institute. Since then, the Chemical Section has held 174 meetings and listened to 215 lectures or papers. A free discussion has always been a characteristic of the meetings. The subjects treated have ranged from the most prosaic details of applied chemistry to the most refined speculations of pure chemistry.

One striking characteristic of the illustrious Franklin was undoubtedly his intensely practical as well as philosophic mind. The Institute which so worthily bears his name, true to its great prototype, has always stood for the happy combination of theory and practice, the union of pure and applied science. But, in no art or industry is the interdependence of theory and practice, the coördination of the laboratory and the workshop, more intimate than in chemistry. The atmosphere of the Institute has,

therefore, been particularly favorable to the development of the chemical arts. Here, in its halls, have met students and workmen, teachers and business men, thinkers and doers; and sitting side by side, each has learnt from the other and all have been mutually benefited.

Aside from this characteristically democratic tone of the meetings, members of the section have been peculiarly favored in several other respects, such that probably no other chemical society in America offers its members equal advantages. Briefly referred to, they are as follows:

(1) The use of the Institute's library and reading-room. The library is particularly rich in old and rare works on chemistry. One of our recent lecturers, coming from Washington to lecture on the history of pneumatic chemistry, expressed himself publicly as surprised and delighted at the wealth of old chemical literature on our shelves, some of the works being so rare that, although familiar with their names, he had never until that time been able to actually see them. Besides these, the wealth of journal literature, that most useful to every kind of chemist, is extraordinary. Among the 400 journals on file in the library, most of them complete, are fourteen concerned exclusively with chemistry, and no less than eighty-three partially. The value of complete sets of American, British, French, Swiss and German patent literature also merits that they be mentioned in even the briefest allusion to the library. Recent works on chemistry are only fairly well represented, but a committee of the section is at present busily engaged in removing this deficiency. Taken all around, it is certainly the equal, and possibly the superior, of any other chemical library in America.

(2) The frequent lectures on live topics by distinguished specialists. The lecture list of the Institute has been particularly rich in chemical lectures of high grade by specialists in their profession. The privileges of members in this regard during the last few years have been exceptional. Time does not permit any further particularization; the presence with us to-night of our distinguished colleague from Washington, to add interest to our proceedings by an

address, will illustrate and emphasize anew this very valuable feature of the section's work.

(3) Immediate and effective publication. The *Journal* of the Institute is unsurpassed among scientific journals for giving immediate and world-wide publicity to its contributions. Passing out to several thousand members and subscribers, finding its place on the files of all scientific libraries, and, particularly, by means of its 400 exchanges entering at once into the hands of scientific editors everywhere, to be quoted, translated, extracted from, discussed—its communications are assured, in the most effective manner, immediate publicity in the scientific world.

(4) The use, at present, of a considerable stock of chemical apparatus; and, prospectively, of a laboratory to use it in. Thanks to the liberality of several members of the Institute, the store of chemical glassware, porcelain, balances, microscopes and photographic apparatus now in the possession of the section is large and costly. Nearly $2,000 worth of such material recently came to us from the estate of Dr. M. Carey Lea alone. This apparatus is primarily for use in illustrating lectures and papers at the Institute, but recent action of the section has placed it at the disposal of any of the members, to be loaned out under suitable regulations.

It is just here that there is a splendid opportunity for extending the usefulness of the section. The apparatus already owned by it would equip several rooms for research work in chemistry, metallurgy, mineralogy, photography, microscopy and allied fields. Such a laboratory would be at the disposal of committees appointed to investigate special questions, or allow any member to translate his ideas and suggestions into experiments. It was a saying of Deville, that "It is not necessary to theorize if you can make the experiment," and who can tell how many bright ideas, valuable suggestions, pregnant thoughts have been called into being at our meetings, and yet have failed of fruition because the member thinking them had not the facilities for making the light-bringing experiment. Great ideas are probably as rare as great geniuses, but it is our

right and duty to nurture them wherever there is a possibility of their developing. May we not express the hope that in the near future the idea of such laboratories may materialize, to the great advantage of the membership and increase of usefulness to the Institute?

The Chemical Section is thus seen to be prodigal in the advantages it offers its members. To the Institute itself it is of service in providing a definite organization for the handling of a definite part of its business. The investigation of chemical questions, the care of the chemical equipment of the Institute, the oversight of the chemical division of the library, the entertainment of distinguished chemists, fall naturally to its committees or members. Granted, however, that a well-arranged laboratory is added to our resources, for which we already possess the equipment, and there may develop a public function or relation of the section to the community which would be by no means unimportant. There are many questions of importance to the community which committees of the section, working in its own laboratory, would be able to solve without fear or favor. Such important matters might be an examination of the municipal water supply, tests of the adulterations in foods, fixing of standards of purity of foods, examination of the material proposed for public monuments, the effectiveness of methods of disposing of sewage, etc. There are, of course, officials already charged with the nominal fulfilment of such duties, but the committees mentioned, rendering unbiased decisions solely for the benefit of the community or commonwealth, would constitute a court of last resort on all such debated and unsettled cases, which would prove of great public value.

We felicitate the Institute and the Chemical Section on the work already achieved. We thank our members for their unselfish devotion, and call on those present to sustain the high standard which has been attained.

We extend a hearty greeting to all our friends who are joining in our celebration, and particularly to visitors and the speakers from a distance, who, at the expense of time and effort, have thus shown their interest in our work.

It is with satisfaction and pleasure that I now introduce the first speaker of the evening, a distinguished colleague, an honorary member of the Institute, ex-President of the American Chemical Society, and Chief Chemist of the Department of Agriculture, Dr. H. W. Wiley, of Washington, the subject of whose address is "The Relation of Chemistry to the Advancement of the Arts."

THE RELATION OF CHEMISTRY TO THE ADVANCEMENT OF THE ARTS.

BY HARVEY W. WILEY,
Honorary Member of the Institute, Chief Chemist to the U. S. Department of Agriculture, Washington, D. C.

[An address delivered in Convention Hall, National Export Exposition, Monday, October 2d, at the Commemorative Meeting of the Chemical Section, on the Occasion of the Seventy-fifth Anniversary Exercises of the Franklin Institute.]

The founding of the Franklin Institute, three-quarters of a century ago, marked the inception of a new relationship in this country between science and the useful arts. In the foundations here laid were provided the means whereby the generations which were to come, who would be deprived of the advantages of academic and technical training in the great institutions of the country, might yet come into touch with science and feel the impetus of its practical application. The provisions here made were not intended for the millionaire, or even the well-to-do citizen, but were planned for the benefit of the artisan, the laborer and the workingman whose intelligence enables them to comprehend the true meaning of science and whose tastes and industry incline them to take advantage of it.

The Franklin Institute was the forerunner of many institutions of similar import which have since been established in the different parts of the country. Among these may be mentioned the Cooper Institute, of New York, the Pratt Institute, of Brooklyn, the Lowell Institute, of Boston, and the Armour Institute, of Chicago. These great centers

for the distribution of practical knowledge are all established upon the general principles which guided the founders of the Franklin Institute in the great work which they have accomplished.

Science, in order to become useful to man, must be vivified by coming into contact with man's industries. It is a misnomer to apply the word "pure" to a science which is latent, and yet we constantly see in the text-books and hear in the lecture-room the expression "pure sciences," meaning thereby research for truths not intended for immediate practical application. I would detract nothing from the dignity of research, nor from the glory and honor of the achievements in the realms of abstract investigation, but I do protest against discrimination which is made or which may be made, in the public judgment, in the use of terms which, to the general reader, may convey a wrong impression. If one branch of science is pure, there is an inclination to believe that another branch is less pure, or is even impure. Whereas, in point of fact, all branches of scientific investigation and application occupy similar positions in their claims upon the attention and the guidance of humanity.

The severely practical man thinks that there is no justification in delving for knowledge for which there is no immediate practical application in view. He should remember that any addition to human knowledge is finally not without some application to human progress, and, however abstract and impractical the results of an investigation may seem, if they afford new light and new knowledge, they will, some day or other, justify the time and the labor which have been consumed in obtaining them.

On the other hand, the devotees of pure research sometimes admit no justification of practical application, and view with contempt the efforts of those who seek to apply for immediate use the great principles underlying scientific investigation. These, however, have some claim for recognition also, and stand upon the same foundation of truth as the scientific anchorite.

If we look casually over the great constructive arts and

industries of the world, we find that they are all practically based upon three great sciences, namely, mechanics, physics and chemistry, and these three sciences are the fundamental ones underlying the great activity of the Franklin Institute. To one who has never had his attention called to this subject, a surprise is in store if he considers carefully the above statement. Whatever be the industry to which his attention is called, he will find that in its inception, its development and its attainments the three great sciences mentioned have played a most prominent part.

Other speakers will call your attention, doubtless, during this anniversary week, to the relations which mechanics and physics bear to the arts. I am invited to-night to say something of the relationship which the science of chemistry bears to the progress of the useful arts. In doing this I disclaim at the outset any intention to minimize the influence which any other science, and especially those mentioned above, may have had upon the development of the industrial life which at present dominates the progress of humanity. While, of course, from my point of view, to-night, chemistry is the chief factor of this dominating influence, you will have this progress exhibited to you from other standpoints before these anniversary exercises are concluded.

During the short time allowed to this address I shall not endeavor to go into elaborate details in regard to any one of the useful arts, but shall rather attempt, in a general way only, to establish clearly the influence which the science of chemistry has had upon industrial development; in other words, to elaborate, at least in outline, the philosophy of industrial development in its relations to chemistry.

Man, in the exercise of his activities, has at his command the raw materials which nature affords, or which he himself produces, and the natural forces which may be directed in the elaboration and utilization of these materials. The changes which matter undergoes in its transformations are, as is well known, twofold, namely, mass changes and molecular changes.

If, for instance, a block of iron ore be transported from

Lake Superior to Pittsburgh, we have change of mass or mass motion. If, after it is left at Pittsburgh, the ore is placed in a furnace and reduced to the metallic state, we have molecular motion, in which the character, properties and appearance of the mineral are radically changed.

Now, in all the industries, no matter what they may be, these changes of the molecular nature of substances are the principal ones to be considered. In the fundamental one of all, namely, agriculture, we see the most striking illustration of this principle. The scientific agriculturist has at his disposal certain elements in the soil and in fertilizing materials, as well as the natural forces, which, aggregated, may be designated as meteorology and climatology; in other words, the forces of water, heat, light and air, in the exercise of his art. His purpose is to transform the elements of plant food into organic products suitable for the nourishment of life and for other useful objects. Every one of these changes is of a chemical nature; in fact, in no industry has the fundamental basis of chemistry been so generally recognized as in the science of agriculture.

In the development of agricultural industry during the past fifty years, there have been founded in all parts of the world agricultural experiment stations, for the study of the principles underlying scientific agriculture. A glance at the names of the directors of these stations will show more strikingly than any other illustration the dominant influence of chemical science. I lately had occasion to look over the names of the directors of the agricultural experiment stations of Germany. I found that more than 70 per cent. of the men who are in charge of scientific investigation, from an agricultural point of view, in the German Empire, are professional chemists.

In our own country, out of fifty agricultural experiment stations now in existence, twenty are directed by professional chemists. But the dominant influence of chemistry in the agricultural stations of this country is not measured by the relative number of professionally trained chemists who are directors of the stations alone, but by the importance of the work done by these stations as compared with

that performed by the others. If one well posted in the matter were asked to name the fifteen most successful agricultural experiment station directors of the United States, I am sure almost every one whose name would appear in the list would be one of the twenty mentioned above.

A much larger proportion of the total number of directors, doubtless, would be found in the chemical profession were it not a very prevalent custom in this country to make the president of the agricultural college also the director of the station, which is usually located at the same place and is under the same board of managers.

Another fact which emphasizes more than those already mentioned the dominant influence of chemical science in the station work is that, of the remaining thirty directors, cited above, very few have had professional scientific training of any kind. In the hasty organization of the agricultural experiment stations of the United States it was found impossible to get professionally trained experts in all cases for directors. In many instances the men chosen had no other preparation than the ordinary college course. Among the station directors, therefore, there is no science which has any prominence whatever, in the way of professional application, aside from chemistry. As an illustration of this, it is only necessary to attempt to name the directors who have been trained as engineers, physicists, botanists, entomologists, geologists or in any of the other well-known sciences. It is probable that there may be one representative of some one of these among the various station directors, but of some sciences there cannot be found even one representative. It may be stated broadly, therefore, allowing for an occasional exception, that chemistry is the one science which is professionally represented in the directorate of the experiment stations of the United States.

In point of fact, the agricultural experiment stations of the United States which have been directed by chemists have taken such a leading position in the development of agricultural science as to practically monopolize all those investigations which have been most useful to agriculture throughout the country.

Among the working forces also of the experiment stations, chemists predominate. There are three times as many chemists employed in the stations as there are those engaged in other professional scientific work. For instance, the number of chemists employed in the agricultural experiment stations of the United States is 157, while the total number of botanists is fifty, and the total number of entomologists is forty-two. Furthermore, the number of other professional scientists employed in the stations is still less even than the number of botanists and entomologists. The number of chemists, therefore, engaged in chemical work in connection with the agricultural stations of the United States is considerably greater than that of *all* others working along other scientific lines.*

The dominant influence of chemical science, however, does not stop with those studies which treat of the processes whereby the inorganic materials of the earth's crust, air and water, enter into organic forms suitable for the sustenance of organic life. Directly following the study of these products is that great class of agricultural chemical technics, whereby the raw materials produced in the fields, gardens and orchards are converted into other products. There is no branch of agricultural chemical technology which is not based upon chemistry and its applications. I need only enumerate the great industries of this class to emphasize my statement. Among these may be mentioned tanning, brewing, distilling, starch manufacture, glucose manufacture, sugar manufacture, wine making and many other similar industries. In each one of these great technical arts, chemistry is the fundamental science whose applications bring success. The time is passed when it is possible to conduct any of these great industries without the direct or indirect aid of chemistry. In many cases a professional chemist is the director or manager of the factory. This is almost universally true of the glucose and sugar manufactories of the world. In the brewing industry the

* If a census were made of the European stations, there is little doubt that the result would be exactly similar.

work of the chemist is of no less importance, although his managerial participation in the work is more limited; and so with all the other industries of this nature.

A cursory study of the processes employed in these great technical operations will show that almost all the progress which has ever been made therein has been due to chemical research. The changes which raw materials undergo in manufacture are almost wholly of a chemical nature. A proper understanding of these changes is the first step necessary to their most economical and perfect operation; therefore, if at the present time all participation of chemical knowledge and its applications in the great technical industries were to be entirely suspended, there would be no further progress in these lines of work, and at the end of 100 years instead of an advance, we would find a retrogression in them all.

I have spoken of agriculture as the dominant industry to which chemistry is particularly allied. I did not do this because I wish to minimize the importance of the other industrial arts with which chemistry is vitally connected, nor because agricultural industries are the ones with which my life-work has been most intimately associated, but because I regard agriculture as the most fundamental art and industry of them all, since without it all the others are impossible. The poorly-fed and poorly-clad nation is the one in which no great industry can thrive. Advancement of a nation in wealth, in power and in influence is conditioned first of all by its food supply; in other words, the development of a nation or of an individual is largely a question of nutrition.

Further than this, the area of the world suitable for agriculture is a fixed one. Man cannot create as well as utilize the fields. First of all, of course, the most fertile and most promising regions are occupied. Little by little the areas less adapted to agriculture are occupied and subdued. When the prairies are exploited the forests are attacked, and when the areas freely watered by the rains of heaven are exhausted, man seeks fresh fields in the arid or semiarid regions. The floods are dammed and stored up for

future use, and the interior of the earth is tapped to secure the supplies of water which flow in the dark secret channels of the subterranean world. But when all these possible areas are occupied, there will no longer be any increasing acreage for the production of human food. On the other hand, we see the population of the earth rapidly increasing under the impetus which the achievements of science have given to man's powers over nature. It is evident, therefore, that the food of the future must be provided by increasing the fertility of the arable soil of the world. Chemistry is the one science connected with agriculture which teaches man to produce his crops and then leave his fields more fertile than they were before. Hence, to chemistry alone the future world must look for its food supplies. And do you ask, will chemistry be sufficient to meet the demands which the future will make upon it in this direction? My answer must be an assuring one. Under the favoring influence of applied agricultural chemistry the fields of the world are increasing their yields. In the north of France the yield per acre of wheat at the present time is nearly double what it was fifty years ago, and this is but one of the instances of what scientific agriculture has been able to do.

Unfortunately, in our own country we have, up to the present time, had little occasion to appeal to agricultural science for help. The fertility of our soils and their vast area have rendered the farmer, to a certain degree, independent of scientific help. But the time has now come when the most productive part of our country is fully occupied. Already we begin to feel the stress of the agricultural population bearing upon the borders of the arid regions, and asking national and State aid for the development of water supplies and the recovery of the arid lands. The level forests and the arable prairies of the humid regions have been fully occupied. In fact, so many of the trees have been felled to make place for the plow as to excite the concern of thoughtful men in regard to the preservation of our forest domain. The time has, therefore, now come when we must look to an increasing yield rather than to an in-

creasing area for the greater food supplies which the future will demand. I, for one, have no doubt of the ability of chemical science to respond to the call which will be made upon it to supply the coming generations, numerous as they may be, with abundant stores of food.

I have spoken thus at length of the intimate relation which chemistry bears to the art of agriculture, not alone because it is the particular theme assigned to me, nor because it is the one which most nearly interests me, but because I believe it to be a question of the most vital importance to our whole people. I would not, however, minimize the importance of the relations of chemistry to the other industrial arts which go to make up the prosperity, the wealth and the glory of our country.

The organization of this great exposition, the first one of its kind ever held, shows you how, in the applied sciences and technical skill of the United States, we are reaching out for the markets of the world. In every one of the technical arts represented in this great exposition chemistry forms an essential part. If I call your attention to metallurgy, which is purely a chemical science, there is, perhaps, no boon, after the production of food, more grateful to mankind than the cheapening of the metals which are necessary to the various industrial arts. Chemical science, combined with mechanical skill, has accomplished this most desired result. Iron and steel not only form the framework of our great buildings which push their attics skywards in our large cities, but I may say that they are the framework and skeleton around which our wonderful nineteenth century has been built. They have as intimate a relation to the progress of mankind as they have to the support of the walls of the building of which they are the frame. By chemical processes many of the ores of gold and silver, which a few years ago were so refractory as not to be fit for use, now yield abundant supplies of the precious metals. The supply of gold has become so great that it has become the money standard of the whole world, with a few insignificant exceptions, and, even in those countries where it is not the adopted standard, we already see signs of a

movement to make it so. Thus, from the metallurgy of this one metal alone, we see that the whole commerce of the world is now based upon a single standard, insuring a degee of stability which has never before been obtained in commercial transactions.

Owing to chemical science another metal also, formerly costly and impossible to use in the arts, has become a common article of commerce. Aluminum, of course, is still in its infancy, and yet we see already that it is destined, both by itself and in combination with other metals, to be of great usefulness to mankind. By reason of its lightness, its toughness and its durability a future day will see it displace the cheaper metals, such as steel, in many structures where steel is now alone employed. I am not here, however, to prophesy the future, but simply to indicate what chemistry has already done up to the present day.

It is unnecessary to multiply instances illustrative of the vital part which chemistry plays in the science of metallurgy, or of the dominant influence which metallurgy has had upon the progress of civilization. Of all the missionaries who have been sent out by devoted men to different parts of the world, it is doubtful if any or all of them have done more to bless mankind than the Bessemer converter.

Metallurgy also holds intimate relations to the art of agriculture, since, in the manufacture of steel from ores and pigs rich in phosphorus, a most valuable fertilizing material, a basic phosphatic slag, has been developed, over a million tons of which are used annually to increase the food supplies of the world. This fact is an illustration of the very intimate relation which chemical research establishes between all the arts and sciences into which it enters.

The science of chemistry has undergone such a wonderful evolution during the past one hundred years as to make some of its branches almost strangers to others. The term chemist at the present day no longer indicates one who is thoroughly acquainted with the entire science of chemistry, but rather one who practices some special branch of the science. There is no living man who can be said at the

present time to understand the science of chemistry as a whole, in the sense of expert knowledge. It is true that one who reads the literature of the day, even in the form of extracts, may have a general knowledge of advanced chemical science and the broad principles upon which it rests. But it requires a lifetime devoted to a special study to become an expert in that line. As illustrated by the intimate relation between two branches of science, apparently so remote from each other as the two cited above, it is evident that there is no real separation between any two lines of chemical research, but that all the workers in this science should recognize their universal fraternity.

Another very apt illustration which will occur to every one, of the influence of chemical research on industrial art, is seen in the development of the coal tar coloring dyes. Fifty years ago coloring matters were mostly natural products, and very few artificial coloring matters were known save those produced by grinding metallic oxides in oil. The vegetable world was the source of a great many of the principal dyes employed in the textile industries. Indigo, madder, turmeric and other vegetable coloring matters were the principal ones employed in the dyeing of many fabrics. To-day we find a complete change in the technique of coloring. From an apparently waste product there have been developed a series of colors which are at once brilliant, permanent and cheap. The development of this industry was due solely to chemical research, without any idea of practical application. As soon, however, as it was discovered that coal tar contained the basis of so many varying tints, rapid strides in their practical application to the textile arts were made. To-day, if the coal tar colors were removed from this industry, it is no exaggeration to say that paralysis would ensue and the capital invested in it, of hundreds of millions of dollars, would be compromised.

Not only in the textile fabrics has this great influence of chemical science been felt, but even in the case of the colors used in food products we find that the coal tar tints are gradually replacing the natural vegetable coloring matters in the markets. We find that candies, confections, pre-

serves, jams, jellies, butter and oleomargarine, at the present time, are colored by tints made from synthetic products, to the practical exclusion of the natural vegetable coloring matters, which, a few years ago, were used altogether. I say nothing here in regard to the hygienic effect of this change; that is a matter which could only be properly discussed upon another occasion. I have spoken only of its commercial aspect, and have endeavored to present to you the triumphs achieved by chemical science in rendering the products of nature more expensive than those of synthetic chemical skill.

This fact leads to the discussion of another very important rôle of chemical discovery in the industrial arts, namely, the continued manufacture of synthetic products, which are cheaper and, therefore, commend themselves more generally to the public use than those formed by the ordinary processes of nature. Chief among these may be mentioned the hundreds of materials now used in pharmaceutical preparations. I have very little to say in favor of the use of drugs and medicines of any description, but in this general review of the accomplishments of chemical research one cannot shut his eyes to the fact that in pharmacy the synthetic relations of chemistry have assumed a very important position. One has only to look over the list of remedies, both official and proprietary, to see the great inroads the chemical laboratory has made upon the fields which heretofore were supposed to be reserved only for natural products. The old natural remedies of herbs and roots are now very largely superseded by the artificial products of the retort and the crucible.

In the case of beverages, we find that a change has been wrought, also, in the substitution, for products made by natural methods, of those produced by chemical synthesis. Especially is this true of those beverages which depend largely for their reputation and flavor upon the ripening influences of age. It is well known that certain kinds of beverages, such as wines and the distilled liquors, known as whiskies and brandies, when properly supervised and kept, become mellower, more palatable and more wholesome

with the passing of time. These changes, which are so appreciated by the consumer, are due solely to chemical reactions which the liquors undergo. In the crude state they contain alcohols which are both unpalatable and unwholesome. Slowly, under the proper conditions, these alcohols are oxidized to form the ethers and other aromatic compounds, which add to the odor and the flavor of the beverage and make it more palatable and more wholesome. The chemist was not slow to discover the nature of these changes, and to produce in a synthetic way, in his laboratory, the exact substances which nature produces in the ripening process. It was found that all these ethers and aromatic substances could be made in the laboratory, and at a much less expense than they could be produced in the bonded warehouse, by natural methods. It was, therefore, possible to mix a pure alcohol with the necessary ethers, essences, flavoring and coloring matters, in the composition of an exact counterpart of a very old whiskey, and this mixture could be made so skilfully that both the chemist and the connoisseur would be puzzled to discover any difference between the genuine and artificial beverages.

Perhaps I should say a word here, also, in regard to the claims which have been made in many quarters that chemical science will eventually permit the synthetic production of human foods, to the practical exclusion of the ordinary pursuits of agriculture. These predictions are not without some foundations in fact, for since the day, now three-quarters of a century ago, when Wöhler and Chevreul succeeded in passing the border line which had been supposed to separate the inorganic from the organic world, and produced actual organic compounds, hundreds of substances of an organic nature have been formed directly by chemical synthesis. Among those bodies which could serve as foods, the fats and sugars are the most prominent, while it is only of late years that bodies having the properties of protein matter have been formed by synthetic operations. Since animal bodies are sustained almost exclusively by food of an organic nature, it is evident that all progress in this line has some bearing upon the food of

the future. The fact remains, however, that all these organic compounds are produced at such an expense as to render them practically impossible for food, even if they possessed all the digestive properties necessary to nutrition. Further, it may be said that organic synthetic products do not seem to have the same relation to the digestive enzymes as is held by the natural products. It seems, therefore, unwise to expect even in the remote future that any considerable part of the food of man will be produced directly by artificial synthesis.

It is true that several distinguished men of science have prophesied the coming of the day when such a consummation would be fulfilled. Chief among these may be mentioned Berthellot, the distinguished French savant, who has foretold the day when all the cultivatable area of the world will be nothing but one grand pleasure park and the surface of this beautiful earth will no longer be desecrated by the vulgar plow. Man, removed from the necessity of toil and living upon the bounty of the chemist, will devote his time to study and pleasure and the millennium, so long expected from theological sources, will at last have come about from the accomplishments of the chemist.

These ideas must be characterized as dreams of the vivid imagination or as the pleasantries invoked for the amusement of an audience, rather than as the sober deductions of scientific truth. I have already indicated the magnificent work which the chemist is doing and is to do for agriculture, but it is not along the line just indicated. The remotest future that the scope of our imaginations can picture, in my mind, will see the food of man produced in the fields and the science of agriculture developed to the highest point of production, chiefly through the accomplishments of chemical science. But, in denying to chemistry the possibility of a complete triumph in the production of all human foods, I do not mean to imply that the prosecution of chemical synthetic research and its application to the industrial arts will not do much to ameliorate the condition of man.

A mere glance at all our industries of the present

day shows how great this amelioration has already become. The capacity of the laboring man to produce useful things, both in the field and in the factory, is increasing day by day, and this increase is due, in my mind, chiefly to the accomplishments of chemical science. It is true that labor-saving machinery has done much, but labor-saving machinery of itself would tend to diminish the demand for labor, and thus to increase the burdens of the laborer. Were it not for the fact that labor-saving machinery, which spares the hands and muscles of the laborer from much drudgery, is accompanied with scientific research, which places the powers of nature more certainly within the control of man, it might prove a curse instead of a blessing. In point of fact, the improvements in labor-saving machinery have been accompanied with an advancement in our knowledge of the laws of nature and of the methods of utilizing to the best advantage the raw materials at our disposal. The sum of all these accomplishments is that a day's labor to-day produces many times more than the result of a day's labor 100 years ago. And this has been accomplished, happily, not by diminishing the compensation paid to the laborer, nor by increasing his hours of work, but, on the contrary, by decreasing his hours of work and increasing his compensation.

A few days ago I was in conversation with an octogenarian who, having amassed a competence, has retired from active business. He said: "Fifty years ago, when I was in active life, money was worth 10 per cent. per annum, and labor could be had at 50 cents per day. Now," he said, "money is worth only 4 per cent. per annum, and labor is worth $1.50 a day." This is a fact which students of sociology should not lose sight of. Unfortunately, most of the so-called sociologists of the present day are pessimists of the worst type. By their ill-based lucubrations they disturb rather than pacify the public mind, since they convince the laboring man that his condition has never been so bad as it is at present, while in point of fact it has never been so good. All the forces which, in the eyes of some people, tend to depress labor, on the contrary, work to

elevate it. It is true that among our skilled artisans the day of the journeyman and apprentice has practically passed away. Scarcely any one at the present day learns to do everything in any trade. Each portion of the work is specialized, and the artisan becomes as much of a specialist as the scientist. Even the "man with the hoe" can earn his $1.50 a day, and while he may not be a master of French art, he finds in his life plenty of opportunities for improvement and culture. His children go to the best schools; his daughter has an organ in her parlor; the family sits at a table spread with wholesome food in abundance; the morning paper brings him the news of the world, and in the grocery store of the village he finds the fruits and delicacies of tropical lands, mingled with the products of the fields about him. The "man with the hoe" of to-day enjoys more opportunities for culture, more of the joys and luxuries of life than did the millionaire of Athens and Rome 2,000 years ago.

We must recognize this state of affairs as progress, any comprehensive study of which will not fail to reveal the master hand of science in it all; nor will it be difficult to see which science has been the most pregnant factor in producing this fruition at the beginning of the twentieth century.

We find in the achievements of science, and in their applications to practical life, the solution of the great problems which have been the theme of philosophers and poets from the beginning of time. The aspirations of the latter and the logic of the former have from the earliest history of mankind been directed to the amelioration of man's condition.

Whatever be our opinion of the theological view of the origin of man, there is one thing in which we must all agree, theologian and scientist alike, and that is the necessity of labor. What the theologian calls the curse of labor, the scientist regards as the glory of mankind. Labor is only a curse when it monopolizes the whole energy of the individual, but it is a blessing when it directs the forces of man into useful channels of expression. The great work of sci-

ence, therefore, for man, is to change the curse of labor into the blessing of labor, and this it is rapidly accomplishing.

I am not one of those who look at the achievements of science in the distant future to see the passing away of the necessity of labor. If the conditions foretold by Berthellot could be accomplished, and man were left at ease in the beautiful garden of his own creation, all the incentives which produced his power would be taken away and retrogression would take the place of progress. It would not be difficult to foresee the time when this very park of pleasure, built by man, would become again a wilderness, in which man and the lower animals would contend for supremacy. Science, by directing man's labor into profitable channels, will make it a means of his own advancement, and the exercise of his faculties will prepare him to enjoy the fruits of his work.

No matter how tempting a feast, both in the quality of its constituents and in the manner in which they are served, it has no attractions for the man without an appetite. Hunger is the prime factor in the enjoyment of a banquet. In like manner one cannot enjoy rest and the pleasures which it brings who has not worked hard enough to make himself tired. Fatigue is the prime factor in the enjoyment of leisure. So even if science could do what some few enthusiasts claim that it can, it would remove from man the necessity of labor, which, when rationally employed under the direction of science, is the source of his greatest comfort and pleasure.

In what has gone before, a few of the most important ways in which chemistry has come into contact with the progress of the industrial arts have been set forth. In the destructive arts and industries, also, the intimate relations of chemistry are quite as well marked. I refer, of course, to the art of war. The radical changes in the art of war have been due chiefly to chemical research. These researches have been devoted mostly to the elaboration of more powerful explosives. In ancient times, before the invention of gunpowder, battles were fought by the actual coming together of the participants. There was added thus to the horrors of war the bitterness of personal contact. Modern

warfare is almost wholly removed from the possibilities of battle by personal contact of soldiers with the enemy. Thanks to chemical science, those who engage in battle are constantly widening the line between the two opposing armies, so that the modern battle is rather a test of chemical skill than a trial of physical prowess. Little by little chemical research has invented means for carrying projectiles further and with greater destructive force. These advances have been met by a recession of opposing forces, so that in point of fact the destruction by battle is decreasing rather than increasing with the invention of better explosives and improved firearms. One hundred years ago a naval battle was not thought to be complete unless the two opposing ships came into actual contact, and the victors boarded the vessel of the vanquished. The slaughter in such cases was something frightful. In our last naval war, armored vessels, securely riding the sea at a distance of one or two miles from the enemy's fleet, proceeded to the bombardment more as if performing an evolution than as if engaging in actual battle. As a result of the application of chemical science combined with mechanical skill, the victors in the two great recent naval battles scarcely lost a man, and the sailors of the defeated vessels were quickly picked up and preserved by their conquerors. The dictates of humanity require that if a war is to be fought, it should be short, sharp and decisive. Chemical invention has rendered it possible to bring even a great war to a speedy close, with an aggregate saving of human life, so that even in the destructive arts and industries chemical science has done much, not only in the accomplishment of speedy results, but also in the conservation of human life.

When it comes to the care of the wounded, chemical science again claims a share of the glory. The antiseptic treatment of wounds is due solely to the study of the causes which formerly made wounds so fatal. At the present day, if the skilled surgeon can reach the wounded man in time, unless the actual loss of tissue is so great as to bring about a fatal result, the sufferer can be saved. The inflammation and the gangrene which have caused the deaths of so many

soldiers after the battles of the past are now practically unknown in the light of modern chemical surgery. Chemistry has furnished not only the theory on which the antiseptic treatment of wounds is based, but the materials which make it possible.

Finally, it may be said that chemical science stands in a fundamental relation to all the principal arts and industries of the world. It also, by making possible an amelioration of the condition of mankind, has done more probably than any other science for what is known as the "humanities."

In former times a liberal education practically excluded the sciences, chiefly because they were not well known, and because they were not considered necessary to the liberal arts. All this is now changed. While we still value and cultivate the old classical and mathematical learning, we have added to it the training in the sciences, which makes the student at the time of his graduation better fitted for the battle of life. For life at best is but a battle, and war, after all, is the normal condition of mankind. It was the struggle for existence that first brought man from the level of the lower animals to have dominion over them. It was the battle of one tribe with another that enabled the superior race of men to people the earth. It is struggle with his environment that develops the power and the precedence of the successful man. While deploring the horrors of war, the sober student of science must admit that it has its uses. Not only does war and struggle bring power and dominion, but it brings also responsibilities and duties which science will show man how to meet and discharge.

The time has passed when the scientific man is regarded as a recluse. He must take his place in the foremost ranks of progress; he must teach his race their powers and their possibilities; he must show struggling humanity the way to succeed and the way to happiness; he must come into contact with the State; he must show the loftiest patriotism and the greatest willingness to assume and practice his privileges as a citizen. In all these duties the chemist will have his full share and chemical science its proper place.

If we may look for one moment at the future, I think we may safely say that in the days to come the progress of chemistry will enter into more intimate relations with the useful arts and industries, and chemical science become a still greater blessing to mankind.

ELECTRICAL SECTION.

THE SEVENTY-FIFTH ANNIVERSARY OF THE FRANKLIN INSTITUTE FROM AN ELECTRICAL STANDPOINT.

BY EDWIN J. HOUSTON, PH.D.,
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[An address delivered in Convention Hall, National Export Exposition, Tuesday, October 3, 1899, on the Occasion of the Celebration of the Seventy-fifth Anniversary of the Franklin Institute.]

The seventy-five years that mark the life of the Franklin Institute have been fraught with much for the world's weal. During this time great discoveries have been made, and great inventions born, in nearly all departments of physical science, but in none of the sciences have these discoveries or inventions excelled, indeed, I may say, none have equalled, those of electric science and its allied useful arts. Both of these have taken their place in the front rank of progress, and bid fair to continue to outstrip all competitors in their useful gifts to mankind. It is eminently fitting, therefore, that the Electrical Section of the Franklin Institute, representing as it does the electric arts and sciences, shall join with others in celebrating the seventy-fifth anniversary of the Mother Institute, in the Convention Hall of the National Export Exposition of 1899.

The wonderful progress of electric science and its allied useful arts, and the marvellous gifts they have bestowed on the world have not, as in the case of many other physical sciences, been spread equally over an extended period of

time. The last century and a half will take in very nearly all the discoveries and inventions made in electricity; the last century will include by far the most important of these discoveries and inventions; the last half a century, the most valuable and useful, and the last decade and a half, the period of their most extended commercial applications.

Our Institute, founded as it was in 1824, began its existence about the time when electrical activity was markedly increasing, existed during the time of its greatest growth, and still exists at the close of that decade and a half when the commercial applications of electricity have assumed such grand proportions. It is fitting, therefore, that we should inquire both as to how well our Institute, devoted as it is to science and the mechanic or useful arts, has availed itself of the advantages of living in an age of such marked mental activity; and as to what share it has had in the development and application of electrical science.

There is, in every age, a mental horizon which forms the limits of man's actual knowledge. Within this horizon all physical phenomena are readily assignable to their proper causes. Beyond it, other phenomena, discoverable only by the prophetic glance, are too dimly seen to be ascribed to known causes.

In the electrical field this mental horizon was for a long time extremely circumscribed, and even when some progress was made and the horizon extended, obstacles to further progress would loom up, offering apparently insurmountable barriers to further extension. Fortunately, one by one these have been swept away, and the horizon of possible conquest, by unwearying research, has been so greatly extended that, in the public estimation at least, there is little that electric science cannot accomplish.

For thousands of years after his creation man was absolutely blind to the existence of any electric force. Although this mighty power was in operation all around him, in the lightning flash, the Northern light and other physical phenomena, yet he remained practically ignorant of its presence, until Thales, some 600 B.C., discovered the curious properties acquired by a bit of rubbed amber. Even

then the electric horizon long remained relatively limited; for, with the exception of an unimportant observation by Theophrastus, about 321 B.C., it was practically more than 2,000 years before any further advance was made into the great unknown land whose shores were thus first dimly discerned. Not until 1600 A.D. had Gilbert and others discovered that many other substances than amber acquired similar properties when subjected to friction. It is true the Chinese were reputed to have been acquainted with the directive power of the lodestone, and to have applied it to practical ends, as early as 2600 B.C.; it is true that some little extension of magnetic knowledge had occurred during the next thousand years or so, and that some little advance had been made in magnetic science by Hartmann, in 1544, and Norman, in 1576, in the discovery of the dip of the magnetic needle. But the intimate relations existing between electricity and magnetism had not yet been discovered, and, consequently, this knowledge failed to influence the limits of the electric horizon.

Before discussing the part played by our Institute in the world's progress in electric science, let us inquire briefly as to what general principles had been discovered at the time of the birth of the Franklin Institute, in 1824. The extent of this knowledge was very limited. Although from the standpoint of that time—1824—this progress appeared to be wonderfully great, yet, compared with what is now known, it was exceedingly small. Reviewing it with necessary brevity, we find that, in addition to the work of Thales, Theophrastus and Gilbert, already recited, Guericke and Hawksbee had produced, in 1675 and 1700, respectively, fairly good frictional electric machines, and that Newton, in 1675, had discovered that electrification imparted to one side of a glass plate produced electrification on the opposite side. No great discovery had been made, however, until Von Kleist, in 1745, invented the Leyden jar, the early type of electric condenser.

This memorable discovery gave an impetus to the study of electricity, which resulted in a fairly considerable advance. In 1752, Franklin, outrivalling Prometheus, had

robbed Jove of his thunderbolts, and with that national characteristic of turning all knowledge to every-day use, had shortly afterwards constructed the first lightning rod. Then, excepting the discovery made by Æpinus, in 1759, and Canton, in 1760, of the phenomena of pyro-electricity or electrification produced in certain crystalline bodies by unequal heating, a period of comparative rest followed, until Galvani and Volta made their famous discoveries in 1786 and 1796, respectively, the former, in connection with the frog's legs, and the latter with the voltaic cell or battery.

Volta's invention of the voltaic cell gave a marked impetus to electric investigations, by reason of the means thus afforded for readily producing electricity, and the nineteenth century opened auspiciously for electric science. In 1800, Nicholson and Carlisle effected the decomposition of water by a current from a voltaic pile, and, during the same year, Henry of Manchester similarly effected the decomposition of sulphuric and nitric acids. Nor did the advance stop here. In 1807, Davy made his immortal discovery of the compound nature of the alkalies, and produced metallic potassium by electrolysis, and shortly afterwards extended his discovery by demonstrating that all the earths and alkalies also compound substances. In 1807, he publicly demonstrated the illuminating power of the carbon voltaic arc. Finally, in 1820, just four years prior to the birth of our Franklin Institute, Oersted demonstrated the long-suspected relation between electricity and magnetism, and thus swept away another great barrier to advance.

In considering the part played by the Franklin Institute in the world's progress in electricity during the seventy-five years of its existence, it will be impossible, in the brief time allotted to this address, to make any attempt to trace, or even to call attention to, the individual work undertaken by its members, in the domain of either pure or applied electric science. Such work has been both varied and valuable, and will be found in the *Journal of the Franklin Institute*, in the reports of its various committees, in the transactions of learned societies, or in periodical literature. It will, I be-

lieve, be more profitable to employ our time in pointing out the aid our Institute, as a whole, has given, and the contributions she has made, to the general advance in electric science that has taken place during this term. And this, indeed, will be the preferable course, since it is the work of the Institute as a whole, and not of its individual members, in which the public is interested in this, the seventy-fifth year of its existence.

Little did those fourteen men, who, in 1824, organized the Franklin Institute, appreciate the importance of the work they then inaugurated. But, fortunately for its progress, none of the essential requisites for success were absent; the originators were eminently capable men; a great public need existed for the kind of work inaugurated, and its growth was intelligently directed; naturally, therefore, the Institute continued to expand until it assumed the fair proportions it possesses to-day.

There is an enthusiasm begotten of comradeship. When men of similar interests associate themselves together for carrying out any work, that work is not only better carried out as a whole, but the individual workers labor more earnestly and intelligently. But, besides this enthusiasm bred of numbers, each worker, strong in some particular direction, complements or fills out weak points in his fellow-workers. The germs of ideas that might, perchance, have slumbered and died, if selfishly guarded by their originators, blossom out into valuable inventions and discoveries in the enlivening environment of mutual work. It is for the same reason that class study is less fatiguing than individual study, and is, moreover, generally more remunerative, since the errors of others often prevent the continuance of errors in ourselves, and the removal of their difficulties aids in the removal of our own. And even when one has reached the necessity to specialize and pursue his studies alone, it is an advantage to come every now and then into mental contact with others of similar, if not identical, pursuits, not only to have enthusiasm enkindled, but also to readily exchange ideas, solve doubts, suggest lines of research, and encourage each other to further advance in the line of his special studies.

The solitary recluse student, who limits his companionship strictly to his own thoughts, may have the good fortune to avoid errors and make fair advance in his special studies, but that advance will be both surer and more rapid if he will but admit into his mental world either the thoughts of others as expressed in books, or, still better, thoughts fresh from the living lips of those who will afterwards publish them in printed characters. But no matter from whence the student gathers knowledge, its value to mankind may be gauged by the extent to which it is freely given to his fellow-student.

Unfortunately for the world's progress, the characteristics of the miser are not limited to the selfish hoarding of money or other forms of material wealth. The mentally rich are often more reprehensible in hoarding for their exclusive use the little store of knowledge they are foolish enough to believe can be kept exclusively their own; or, if they share such knowledge at all, it is only with little exclusive coteries of their own, for self-glorification. These pigmy mutual admiration societies, whose members are occupied mainly in sounding each his own praises and magnifying his own achievements, aid but little in the general progress of the world. Their mental world, in their belief, is so far uplifted beyond that of the rest of mankind that they are unwilling to have it enter into their lives, and when they have anything worth publishing they too often phrase their discoveries in language unintelligible save to those belonging to their exclusive set.

Associations formed of such men never have and never will develop phenomenal growth. What discoveries are made by any of their members will practically remain a dead letter. It is no excuse to plead that certain lines of study are so abstruse that it is impossible to describe them so as to permit any but those especially skilled even to faintly comprehend, much less to thoroughly grasp them. This is not true. An idea, no matter how complex, if thoroughly understood, is capable of analysis into its component ideas, and these, necessarily elementary, are readily susceptible of being so phrased as to be thor-

oughly grasped by others. He who assumes that his ideas are so far removed from the range of the average intellect that it is useless for him to attempt to appeal to it, and who adopts a mysticism in giving them to the public, not only renders such publications comparatively worthless, but even renders himself liable to the suspicion of but vaguely comprehending the ideas himself.

Some apologists for exclusiveness in scientific research have endeavored to erect a barrier between pure and applied science. While, of course, a distinction necessarily exists between the two, yet the lines of demarcation are by no means sharp, and it is worse than foolish to attempt to keep them apart. Ideas, evolved by the so-called pure scientists, that are incapable of being put to practical use, are shadowy and unsubstantial, and unworthy of being ranked as great ideas.

Another unsound contention of these scientific exclusionists is that the investigator is degraded by actually putting his discoveries into operation for the benefit of his fellow-man. Fortunately for the world, these ideas were not shared by such grand investigators as Morse, Henry or others of their type. Indeed, it is impossible for one to become a great physical investigator who does not continually subject his theoretical deductions to proof by actual trial. It is folly to maintain that he who aims at discovering the laws of nature can make any marked advance without constantly interrogating her by actual experiment. When certain deductions have been made and a generalization reached, if the investigator fails to test the correctness of such investigation by trial, he will, most probably, fail to achieve further advance into the unknown. Conclusions based on laboratory experiments carried on by minute quantities of material and comparatively feeble forces, and those conducted on a commercial scale, are perhaps equally reliable. But no one can deny that the most conclusive test of the correctness of any general physical law is obtained by commercial results rather than those of the laboratory. When a machine embodying the principles of a great invention has been reduced to a drawing, much has been done. But

such a machine cannot be regarded as actually completed until it has been put into gross material and employed in doing actual work.

The magnificent exhibits of the National Export Exposition that are to-day offered for our inspection have been rendered possible only by the carrying out of such lines of action. They are the natural fruits of great ideas embodied in practical working machines or processes.

The Franklin Institute has achieved the marked growth it possesses to-day because its work has possessed the following characteristics, viz.:

(1) Co-operation of work undertaken jointly by men learned in books and men learned in things, a great working brotherhood of theory and practice.

(2) The widest possible publication, in language intelligible to all, of ideas born in its midst, or presented to it for consideration.

(3) Reduction to practice, by subjecting all discoveries and inventions to the test of actual, every-day use, thus carrying out the purpose for which it was incorporated; viz., "The Promotion and Encouragement of Manufacture and the Mechanic and Useful Arts."

For the proper carrying out of these characteristic types of work the Institute has its Regular Monthly Meetings, its valuable Library of Reference, its Memorial Electric Library, its Historical Collections, its various Sections, its Popular Lectures, its Committee on Science and the Arts, its Drawing School, its *Journal of the Franklin Institute*, and last, but by no means least, its Exhibitions or Expositions. It is far from my purpose to refer to these in detail. They are enumerated merely to permit you to readily see how ample are the means the Institute possesses for carrying on its work along the directions already outlined.

The Franklin Institute has carried on important work of the above-named characteristic types in all the physical sciences. But, as representing the Electrical Section, we are to-night mainly interested in electric science, and in this direction the work of the Institute has been of a character of which we may justly be proud. Through all its

characteristic types of work it has contributed freely to advance in electric science, and we might profitably examine in detail contributions of each of these agencies did time permit. Without any desire to belittle the work of the other agencies, I will ask you to examine briefly with me one only of the most conspicuous of these; namely, that of the International Electric Exhibition of 1884, and this, I think, we are justified in doing, since this particular class of work was strictly limited to electrical devices and applications. I might, indeed, well expend the time in considering the work of our Electrical Section, but, since the Exhibition was held at its suggestion, I think a consideration of the work of this exhibition will suffice.

The Electrical Exhibition of 1884 assumed its international character by virtue of an Act of Congress approved February 26, 1883. Like the present National Export Exposition, it was located in West Philadelphia. The conditions were especially favorable for the holding in this country of an exclusively electrical exhibition. The movement favorably attracted the attention of electric scientists and of manufacturers of electrical apparatus in all parts of the world, so that the exhibition contained electrical devices, apparatus and machinery from all parts of the world. Every branch of electric science contributed some exhibits of the most interesting type; namely, working exhibits, interesting as showing the mastery that had been achieved in those branches of electric science that had produced such exhibits, thus putting the electric forces to every-day work. Besides, there were interesting historical exhibits.

The extent and variety of the different exhibits excited wonderment in the minds of the many visitors. To those unacquainted with electric science, a wonderment that it covered so extended a field; to those fairly acquainted with the achievements of electricity, a wonderment that these achievements so far exceeded in number and variety what they had heretofore credited it with; to those from distant countries, or distant parts of this country, a wonderment that other countries, or other parts of this country, had so far ad-

vanced in their products; to capitalists, a wonderment that so promising and varied a field was offered for profitable investment; to those of an inventive mind, a wonderment that so much room still existed for improvements in existing methods of application, or for work in new directions. The environment of the exhibition favored unusual electrical growth, and subsequent facts amply show that the expectations for such growth were fully realized.

True to its general policy of educating the masses, the authorities of the Franklin Institute proceeded to utilize the occasion to increase the knowledge of its members and visitors. Besides the numerous working exhibits, it collected an admirable historical exhibit, showing the gradual growth of electric apparatus and appliances; it began the collection of a valuable Memorial Electrical Library, it gave to the visitors the names of the different apparatus exhibited, by suitably placed cards, and for further information referred the visitors to printed placards describing the apparatus in detail—placards that were afterwards amplified and issued in the shape of Primers of Electricity; it had courses of public lectures on electrical topics delivered by eminent scientific men, as well as special lectures prepared for the children of the public schools. The exhibition thus became a great school for all sorts, conditions and ages.

During the progress of the exhibition, and called together by reason of its existence, there was assembled a United States Electrical Commission, appointed by the President of the United States under authority of an Act passed by Congress, May, 1884. Under this authority the Commission conducted a National Conference of Electricians, wisely including in its invitations to such conference both men eminent in electrical science and men eminent in the electric arts in this and in other countries.

It was practically in the International Electric Exhibition of the Franklin Institute that the great American Institute of Electrical Engineers had its birth. This great body of eminent electricians that has done so much to create and direct electrical science, both in this country and abroad, may, strictly speaking, be claimed as the child of the Frank-

lin Institute, and, although it is to-day an independent and separate body, yet the friendly relations still existing between the two Institutes may be inferred from the fact that out of the twelve presidents of the American Institute of Electrical Engineers, five have been selected from members of the Franklin Institute, and that during the nearly fifteen years of the existence of the American Institute of Electrical Engineers, eight of these years it has been presided over by a member of the Franklin Institute.

It is difficult to properly estimate the beneficial effects produced on the progress of electric science and its allied useful arts by the mere coming together of such bodies of men in an environment so essentially electric. The wonderful possibilities of electricity, though generally appreciated before the time of the exhibition, were then more clearly seen, and the foundation was laid, certainly in this country, and, most probably, in other countries as well, for that marvellous growth in the commercial applications of electricity which has taken place since the time of the exhibition.

It is far from my desire to claim for this special work of the Franklin Institute that it was the sole influence that determined this subsequent phenomenal growth. It is sufficient if I have shown that it was a directing cause. I certainly feel justified in claiming that never before in the history of this country, and, perhaps, never since, has so much been done to further and foster the electric arts than has been accomplished, both directly and indirectly, by the International Electric Exhibition of 1884, undertaken under the auspices of the Franklin Institute of the State of Pennsylvania.

In inquiring as to the part our Institute has taken in the advances that have been made in electric science during the past seventy-five years, let us briefly consider some of the more important that have been made during this period. We are to-day practically at the beginning of the twentieth century. The seventy-five years we are about considering practically constitute the second, third and last quarters of the nineteenth century. While we can conveniently consider the advances made during this time as the

second, third and last quarters of the nineteenth century, yet it will be advantageous to consider the last quarter, especially with reference to its last decade and a half. In other words, we will divide the three-quarters of a century into two parts, viz., the sixty years prior to 1884, and the fifteen years subsequent to this time. I do this designedly to call your attention to the marked influence the Electrical Exhibition appears to have had on the electrical activity of the entire world; for, we will find that by far the greater bulk of era-making applications reached their most extended commercial extension after 1884.

Of the discoveries made prior to 1884, let us first briefly consider those of the second quarter of the nineteenth century. Oersted's great discovery was almost immediately followed by Ampère's valuable researches, so that, quite naturally, the beginning of this period was noted for the production of the electro-magnet, in substantially its present form, by Sturgeon, in 1825, and by Henry, in 1828. The wonderful extent to which electro-magnets enter into the structure of nearly all modern electric appliances will give some idea of the value of this invention.

But another discovery was made in this quarter of the nineteenth century that was even more important than that of the electro-magnet. I refer to Faraday's immortal discovery, in 1831, of magneto-electric induction. This was the reverse of Oersted's discovery of the production of magnetism from electricity, since it showed how electricity could be produced from magnetism. Faraday demonstrated that when a coiled keeper was suddenly separated from a permanent magnet a spark was produced; that when a permanent bar magnet was suddenly thrust into or withdrawn from a coil of wire, an electric current was set up in the coil, flowing in one direction on the insertion of the magnet, and in the opposite direction on its withdrawal. He also laid the basis for the subsequent invention of a practical dynamo-electric machine by demonstrating that an electric current was produced in a copper disc by rotating it between a pair of magnet poles. All these in 1831.

Faraday's discoveries soon led to the production of fairly

efficient magneto-electric machines, the forerunner of the modern dynamo. Such machines were produced by Dal Negro and Pixii in 1832, by Saxton in 1833, and, subsequently, by Clarke, Ritchie, Jacobi, Sturgeon, Wheatstone, Cooke, Nollet, Von Malderen, and many others. In 1854, Hjorth had discovered, and practically applied, the reaction principle, whereby the currents generated in the armature coils were utilized to strengthen the magnetism of the field, the armature and the field, thus mutually aiding each other until the machine "built up," or became capable of producing its full working current. This principle was independently discovered, either partially or completely by others, especially by Varley, in 1867, and independently by Werner Siemens and by Wheatstone in the same year. Numerous inventions followed, the dynamo of the third quarter of the nineteenth century, reaching its practical culmination in 1870, in the then famous generator of Gramme.

Naturally, the invention of the electric motor also followed Faraday's discovery, so that this important application of electricity also belongs to the second quarter of the nineteenth century. As early as 1831, Henry had suggested and described methods for utilizing electro-magnetism as a motive power. Dal Negro made similar suggestions in 1833, and Jacobi in 1834, and Page in 1850, had produced operative electric motors.

During this period the electrolytic power of the current had been practically applied by Jacobi, who, in 1838, had invented the art of galvanoplasty or electrotyping, whereby the cold casting of the metals might be effected by electrolytic deposition. Elkington and Wright, at a somewhat later date, had made important applications in the same direction. It was also during this period that Ohm, in 1827, made his great generalization concerning the flow of current in the electric circuit.

Another exceedingly important invention of this second quarter of the nineteenth century was that of electro magnetic telegraphy, rendered possible by the production, in 1836, by Daniell of his constant voltaic cell. Consequently, the next year, 1837, was memorable in the annals of tele-

graphy, since during it Morse in America, Steinheil in Munich, and Wheatstone and Cooke in England, produced electro-magnetic telegraphic systems that are substantially similar to those employed to-day. Ever since this date telegraphy flourished, and in 1858, near the beginning of the third quarter of the nineteenth century, Field had accomplished the laying of the first Atlantic cable.

The early part of the third quarter of the nineteenth century was largely occupied in telegraphic matters. The suitability of gutta-percha for the insulation of submarine cables was recognized, the phenomena of electric charge in telegraphic wire carefully studied, the existence of earth currents demonstrated, and various improvements made in telegraphic apparatus. This part of the period culminated in the laying of the Atlantic cable in 1858.

It is interesting to note that this laying of the Atlantic cable, requiring, as it did, the investment of considerable capital, necessitated a more accurate knowledge of electric laws, and so laid the foundations of electric engineering, which may properly date its origin from this time. It is true that frequent efforts had been made before 1858, to introduce the electric light on an extended commercial scale, and that Staite, Petrie, Foucault and many others had produced fairly operative lamps, but the electric current, as furnished by voltaic batteries, was too costly, and these efforts signally failed.

The last quarter of the nineteenth century, as you are all aware, has been a period of marvellous activity in electric science. The excellent dynamos of Gramme, Siemens, Halske, Hopkinson and others in Europe, and of Brush, Weston, Thomson-Houston, Edison, Crocker-Wheeler and others in America, assuring, as they do, the production of cheap current, have rendered possible many extended commercial applications of electricity. For example, another attempt, and this time a successful one, had been made for the extended commercial introduction of electric lighting. Improvements have been made, by the above and others, in generators and lamps for arc and incandescent systems, both by direct and alternating currents; and the

commercial applications of electric lighting that exist to-day, at the close of the last quarter of the nineteenth century, have assumed enormous proportions.

As we have seen, improvements in arc lighting were extended over a comparatively long period of time. The same is true of improvements in incandescent lighting. As early as 1845, King had invented a lamp whose light was due to the electric incandescence of a small pencil or thin plate of carbon in a Torricellian vacuum. Roberts, in 1852, had produced a light by incandescing conductors in a high vacuum. More recently these have been followed, among numerous others, by Lane-Fox, Swan, Maxim, Sawyer-Mann and Edison, especially the latter, who have produced the efficient incandescent lamps of to-day.

Near the beginning of the last quarter of the nineteenth century, in 1876, another era-making application of electricity was accomplished by Bell in the speaking telephone. Bell's invention was an improvement of Reis' prior telephone of 1861. The telephone has, during the latter part of this period, attained a marvellous growth, and is to-day a formidable rival of the ordinary telegraph.

The application of the direct electric current to systems of street-car propulsion is another direction in which enormous progress has been made during the last decade and a half. But probably in no direction has progress been so great as it has in the field of alternating electric currents. Though known long prior to 1875, yet their marked extension commenced at a comparatively recent date. Short as this time has been, it has sufficed to almost create a new science within a science. Electric power transmission on an extensive scale has also been rendered possible by means of alternating-current apparatus.

As to electrical progress since 1884, the time is so recent, a mere decade and a half, that the prominent developments are still fresh in your minds, and might, therefore, be left to what has already been mentioned in connection with the last quarter of the nineteenth century. But so much has been accomplished during this time, and the part our Institute has played, especially in its International Electrical

Exhibition, in determining and shaping this progress has been so important, that we can well devote some time to a consideration of the most important of these developments. If the nineteenth century may be referred to as the Age of Electricity, its last decade and a half may pre-eminently be regarded as the Age of Commercial Electricity, the time during which electric arts have reached their highest development. Indeed, this trait may possibly be the characteristic feature of the twentieth century, so far as electricity is concerned.

Taking up the commercial applications of electricity which have attained phenomenal growth during this time, without strict reference to their chronological order, we will first consider street railways. The replacement of the lumbering stage and omnibus by the horse car, on the tramway or car track, and the partial replacement of the latter by the cable car had already occurred. It was about 1884, that the peculiar fitness of electric traction for the work led to its extensive introduction, and, so rapid has been its adoption since that time, that to-day there is scarcely a horse car to be found in any of our large progressive cities or towns.

Electric traction is pre-eminently one of the commercial applications of electricity that have offered an attractive field for the remunerative investment of a vast amount of capital. Some idea of the extent of this investment may be obtained from the fact that, in the United States alone, the gross receipts of some 222 street railways reached, in a single year (1898), the vast sum of about $128,000,000. Of these 222 roads, some 26 had annual gross receipts of $1,000,000 or over; some 20, annual gross receipts of between $500,000 and $1,000,000; some 58, between $100,000 and $500,000; some 62, between $50,000 and $100,000, and the remainder between $25,000 and $50.000.

Although alternating electric currents, transformers and polyphase motors have been known long prior to 1884, yet their extensive commercial application has been subsequent to that date. The comparative simplicity of the armatures of polyphase motors, their long life under continual use,

and their powerful starting torque give them advantages over continuous-current motors that the commercial world has been prompt to recognize. Moreover, the readiness with which alternating electric currents, in connection with the modern transformer and polyphase motors, lend themselves to the economical transmission of energy over considerable distances, has caused the system to be almost exclusively employed for electric power transmission. In addition to this, we may add the extensive practical application of alternating currents to electric lighting, both arc and incandescent, and to heating, welding and some forms of electric furnaces.

The following estimate as to the total production of alternating-current apparatus in the United States in 1898, will give some idea of the extended use of this type of electric apparatus, viz., total estimated production of alternating-current generators and motors, 120,000 horse-power; of transformers, 750,000 lights capacity, and of meters, 750,000 lights capacity.

Although, as we have seen, the storage battery had its origin in Planté's secondary battery of 1859, it was not until 1884, that it was capable of extended commercial application. As it exists to-day, its efficiency and length of life under the requirements of actual use have permitted it to come into very extended every-day use, not only for general purposes, but also in electric light and power stations for the purpose of adding to the total output at the time of maximum load. Another use for the storage battery, that promises great developments, is its use for the propulsion of automobiles. The growth of this comparatively new branch of electric science bids fair to assume enormous proportions in the almost immediate future.

Extended commercial applications of the telegraph and the telephone, especially the latter, have been especially marked since 1884. The fundamental apparatus of both the electro-magnetic telegraph and the speaking telephone were invented long prior to this date; the telegraph in 1837, and the telephone in 1861; but while the extended commercial application of the telegraph was made long prior to 1884,

Field having laid the first Atlantic cable in 1854, the extended commercial application of the telephone has been since that time. I will permit you to infer its marvellous growth from the case of a single city, say New York, where, in 1895, there were about 10,000 telephone stations. In August, 1899, there were in the neighborhood of 33,000 stations, thus rather more than trebling the number in less than half a decade. New York City to-day, that is, the old city together with the boroughs of Manhattan and the Bronx, is said to have more telephones than London and Paris together.

The practical commercial application of electro-magnetic waves has been accomplished since 1884. The existence of electro-magnetic waves had been recognized long before this time. As early as 1842, Henry of Princeton observed that steel needles placed in the cellar of his house, were magnetized by a condenser discharge in an upper room. Maxwell, in 1864, had announced his hypothesis as to the practical identity between electro-magnetic radiation and ordinary light, and in 1888, Herz, by employing the principle of resonance, had corroborated Maxwell's hypothesis, showing that electro-magnetic waves possess practically the same velocity as light. Finally, Marconi and others have applied these principles to the transmission of intelligence, and wireless telegraphy is being put to actual use; and although the probabilities of its ever becoming a formidable rival of existing telegraphic systems are somewhat remote, yet it possesses great future possibilities.

The so-called X-rays form, most probably, another variety of electro-magnetic waves that has come into extended commercial use since 1884. Their peculiar behavior as regards many substances opaque to ordinary light (itself a form of electro-magnetic radiation) has rendered them of great practical value in connection with photography, for accurately locating the position of certain foreign substances in the human body, as well as indicating abnormal conditions of its tissues, organs, etc. The Wehnelt interrupter, which has been of so great service in connection with the induction apparatus used in X-ray work, has also been introduced since 1884.

Electric lighting, both arc and incandescent, has shown an enormous increase in actual use since 1884. The number of electric lighting stations now existing in the United States is by no means limited to the number of cities and towns in this country. In nearly all large cities there are separate stations provided for different localities. Moreover, the number of isolated plants in all our large cities and towns is considerable, some of which, in the case of tall office buildings, are almost sufficiently large to equal in their output that of moderately large central stations. For example, in the city of Boston there are, according to a recent report, no less than twenty-nine generating stations and 195 isolated plants. The dynamos in operation have a total capacity of 424,443 incandescent lamps and 10,094 arc lamps, which, including some 7,070 electric motors, require some 90,382 horse-power of boilers and 66,774 horse-power of engines.

The part which electricity, mainly since 1884, has come to play in our lives in great cities is manifold. We light our streets, our public buildings and our houses with it, drive our street cars, transmit messages by telegraph and telephone, operate annunciators, protect our buildings by fire and burglar alarms, drive motors, rotate fans, bring cheap power from distant waterfalls to our doors, install electricity for varied purposes on our war vessels, and employ it in many other ways, which will doubtless suggest themselves to you.

This extended commercial use of current calls for the manufacture of much apparatus. Looking over the annual report of a single large company in this country, we find that for the year ending January 31, 1899, the total sales, as billed to customers, amounted to more than $17,260,000, and this, good, profitable business, the calculated direct profits amounting to more than $2,500,000. Some idea of the business done by the company in electric lighting may be inferred from the fact that during this term the orders for incandescent electric lamps reached 8,400,000 lamps!

The manifold uses of electricity to-day in our modern cities mean the employment of a vast number of electric

wires and conduits, both overhead and underground. Take, for example, the city of Boston. There are, in this city, according to a recent report, of underground wires alone, 726,997 feet of conduit; 3,469,011 feet of duct; 5,427,482 feet of cable; 167,751,793 feet of single conductor in cables.

The enormous demand for electric apparatus has not been without its effect on the price of copper, which has advanced materially during the past five years, rivalling even the increase in the price of zinc, lead and iron.

Such is the record of the seventy-five years during which the Franklin Institute has existed. That it has exerted a marked influence on the extension and application of electricity, not only, as I have endeavored to point out, by its great International Electrical Exhibition of 1884, but also through the many other kinds of work by which it endeavors to extend electric science and ensure practical applications of the same, I believe none will question. Regarding to-night the growth attained by electric science during the nineteenth century, we may well exclaim with Morse, "What hath God wrought?"

THE INFLUENCE OF TECHNICAL SOCIETIES IN PROMOTING THE PROGRESS OF THE ARTS.

By RALPH W. POPE,
Secretary of the American Institute of Electrical Engineers.

[An address delivered in Convention Hall, National Export Exposition, Tuesday, October 3d, on the Occasion of the Celebration of the Seventy-fifth Anniversary of the Franklin Institute.]

When we consider the vast strides made during the century in practically every branch of applied science, or even the advances made within the memory of the youngest among us, it is not now difficult to realize that seventy-five years ago there existed a field for the Franklin Institute.

That it survived, and is now active along the lines projected by its founders, proves, beyond question, the wisdom

of those whose memories we unite in honoring to-day. A record of seventy-five years devoted to the encouragement of art and science is most enviable, and whatever may happen, no break in its continuous career should ever be permitted.

Here has been maintained, through peace and war, through prosperity and adversity, a forum where every struggling scientist and every hopeful inventor might meet with the encouragement that stimulates, or that kindly criticism which frequently leads to well-merited success.

It has been the good fortune of the Franklin Institute to watch beside the cradle of the infant steam: to observe the gradual development of this mighty force, until upon its foundation there has been erected the new and gigantic electrical industry which through ignorance is frequently considered its rival and possible successor. The builder of the steam engine has seen no wave of prosperity which will be so enduring and so satisfactory as that which has followed in the wake of the electric generator and motor.

While the utilization of water power for the generation of electricity is important, nature has arbitrarily confined this practice to a comparatively few and limited districts, so that to-day, and, so far as we can predict, in the future as well, the steam engine as a prime mover is without a rival. The power having been developed, what may we not accomplish through that unequalled distributing agency, the electric current?

Just as the steam railroad had entered upon its useful career, the world was startled by the successful invention of the electric telegraph, the first example of instantaneous transmission of power to a distant point. Still mankind had lived and multiplied, nations had arisen, cities had been founded and fallen into decay, great battles had been fought, literature and the arts had flourished. The steam engine, however, was unknown, and the telegraph was but a dream.

Even to-day, surrounded, as we are supposed to be, with every possible convenience and luxury, men and women may be found living happy and contented lives who have

never sent a telegram, nor seen an electric car. Consider Alaska, until recently without a railroad or a telegraph, where only hardship, famine, disease and possibly death were reasonably certain; where men have fallen in exhaustion overladen with gold, which brought no food where food did not exist. But men with stout hearts and sturdy muscles have left comfortable homes and lifelong friends to grapple with cold and hunger in order to wrest from nature's secret storehouses the golden nuggets which have been hidden for ages in that hitherto almost inaccessible spot.

We have assembled to-day, however, to eulogize the influence of science upon the advance of civilization. We are here to assert that the world is growing better, even as we believe it is growing more comfortable. Brief as may be our pilgrimage, we live longer, or rather, as we journey through life, our experience is greater. The world's history, thanks to the press and the telegraph, is spread before us each day as important events occur. The thread of sympathy with the distressed entwines the hearts of every nation, and again, in the words of the Psalmist: "Let the earth rejoice," for is it not known throughout all lands that Dewey has received the grandest welcome of ancient or modern times?

Even this great outburst of patriotic enthusiasm is a tribute to scientific research. Without the aid of steam or electricity the concentration, within so short a space of time, of such a multitude from all portions of the country upon Manhattan Island would have been an impossibility.

Step by step, during this wonderful nineteenth century, we have watched the growth of these marvellous achievements until we have been educated to the belief that there is practically no limit to the stride of invention. When we consider the perfection of modern mechanical methods, however, the results obtained in early days should excite our admiration.

Fifty years ago the steam locomotive had a speed record of a mile in a minute, and the general improvement in schedule time since that period has been largely due to a

more perfect track and longer runs rather than to any radical change in the original machine. With the same machinery used fifty years ago the skilled Morse telegrapher could do as rapid work as he can to-day.

In both cases the original idea appears to us now as exceedingly simple. Subsequent perfection in details has been a process of evolution. During all this time a small army of inventors had grappled with the problem of a type-setting machine, and not until within the last ten years has success been attained. The germ of a great invention is a tender plant. It must be nurtured with extreme care. It is for the encouragement of these early steps in the advancement of an art that this institution exists.

Once success in an art is attained, popular enthusiasm will soon place it beyond the reach of adversity. Too frequently the original inventor, and even the sanguine financial promoter, fail to reap their just reward, but the idea lives, and the people are benefited by the improvement.

Notwithstanding the important bearing which science and mechanics have upon our national progress as well as our personal comfort and satisfaction, your attention is directed to an apparent omission in our educational system. It is quite certain that scientific and engineering societies would be more generally appreciated and more heartily supported, if students were more thoroughly trained at an early age in elementary physics. They should also have an opportunity for practical work in wood and metal with good tools. If they have no inclination toward work of that character, the experience will do them no harm, while in the majority of cases the knowledge thus gained will be of great use to them later in life.

Within the past few years more attention has been given to manual training, but there are still, no doubt, thousands of schools in the country where there is no attempt to master even the simplest scientific facts.

As I travel daily between New York and my home at Elizabeth, the Staten Island shore is plainly visible. Years ago a vessel laden with oil took fire and was beached at the northern end of the island. The oil continued to burn for

a day or two, and the novel sight naturally attracted the attention of the passengers. Directly in front of me two intelligent-looking gentlemen laid aside their morning papers for a moment and began talking about the fire. One of them said he supposed that what they saw was the burning oil floating on the water. "I know oil will float on the water," said his companion, "but I'm not sure whether it will float when it is in barrels." "Neither am I," was the reply. Here were two men, either of whom knew that oil would float on water, and either of whom was probably certain that a barrel would float, but whether the two combined would float or sink was beyond their comprehension.

It is not necessary that we should know what electricity is, or what gravitation is, or account for the existence of what is known as permanent magnetism. We can, however, readily master certain laws based on scientific facts. We can assure ourselves that, under certain conditions, certain results will be accomplished. There is no reason why these facts should not be thoroughly grasped in childhood. There are no toys so interesting to the young as what are known as scientific toys, and if parents are neither willing nor capable of teaching their children these important truths, we should see that they are generally taught in school. The prevailing ignorance in such matters is responsible for the existence of a class of alleged inventors who devise schemes for obtaining money under false pretences. Most of us are familiar with examples of this fraudulent practice, and Philadelphia has been a favorite field of operation. The notoriety attained by such impostors has reacted upon honest inventors, who frequently lack capital to develop their ideas. There is but one safe course for an innocent but honest investor. He should seek the advice of an experienced and competent expert familiar with the field which is to offer a market for the invention. If he is not financially able to pay for such an opinion, then he is not in a position to take the risk of a doubtful investment.

It is too frequently the case that the investment is made first, and the expert called in after thousands of dollars have

been squandered. There is always an air of suspicion hanging about these questionable enterprises. Some vital link is a profound secret. There is a mysterious chemical compound or some unaccountable manifestation of force casually referred to by the exploiter that should place every investigator on his guard. It is not necessary that an expert should be expected to explain a manifestation when he is morally certain that something is hidden from him.

On the other hand, it is not always well to place too much confidence in the statements of the really honest inventor. His mind may be biased by his enthusiasm, and without intent to mislead, he may neglect to call attention to certain facts which would detract from the usefulness of his improvement.

Having guarded all these points, however, there is still another test to which an important invention may be subjected. Let it be exhibited and accurately described in open meeting before such a society as the Franklin Institute or the American Institute of Electrical Engineers. When the subject is thrown open for discussion, the demonstrator must have his wits about him. He will find that flaws exist which he never dreamed of. He will learn that even if his apparatus works, there may be a dozen reasons given why it ought not to work. He will be surprised to find that the cost will be so much greater than under existing conditions, that no one will have anything to do with it. He should not be discouraged by these slighting remarks. There are always people who think that anything new is not good, and anything good is not new. If his machine or process works, he can disregard the reasons why it should not. If it is a decided improvement, he should remember that good things are frequently expensive. People do not continually eat "pork and beans" because experts say the dish is nutritious and cheap.

It is not my intention to ridicule free discussion, but rather to call attention to its value in bringing to light all the bad as well as the good features of an invention, or the merits and demerits of a process, or the strong and weak points of a line of practice.

There is another great influence exercised by a society of this character, which, unfortunately, we cannot accurately determine. Experience shows, however, that it must exist. During the interchange of ideas, the brain is stimulated to unusual activity along the lines made prominent by the subject under discussion. New thoughts are developed and improvements are suggested. For the moment a participant becomes a worker in possibly a virgin field. He groups the facts gleaned from his experience, and, as a result, another improvement comes to light. The suggestion may be thrown out as a free gift, or it may be withheld for the time being, and eventually brought out in independent form.

Frequently men of high professional standing who cannot be induced to write a paper, or an article, will gladly participate in a discussion which has awakened their interest, and the world's record is enriched by thoughts which might otherwise never have been revealed.

Notwithstanding the classification or specialization that has gradually developed in the general field of engineering, the training which each individual receives leads him to gradually absorb a great deal of information which is not in his own line. Thus an electrical engineer should be, and frequently is, well versed in mechanical engineering. The civil engineer and the mining engineer should be familiar with both mechanical and electrical engineering in order to determine the best application of power under existing conditions. Although all citizens should be interested in the construction of public works in the best possible manner, in order to give really intelligent opinions, they should be trained engineers. There is a good reason for this, as years of study and experience are required to enable a man to intelligently select from different materials that which is best suited for a contemplated improvement. Take the question of pavements, for instance. In some cases the residents along a street are called upon to decide what kind of a pavement they prefer. Various conditions must be met, and each person is expected to contribute his own views to the discussion. He may want Telford because it is the cheapest, or Belgian because it is

most durable, or asphalt because it is noiseless, or brick because he has heard that it was better taking all things into consideration. It is the life-work of an engineer to study and compare all these conditions, and it is his constant aim to get the very best results at the least possible expense. Professional pride will not permit him to authorize improper materials, for his reputation is based upon the character of his work.

If the engineer was more freely consulted in even what are considered the minor details of all public work, better results would be obtained. An eminent New Jersey judge recently made the statement that, during thirty years' experience, while every contractor for public work had been required to file a bond of guaranty for the faithful execution of his agreement in accordance with specifications, there had been no instance of suit being brought for recovery of damages on account of defective construction. This does not prove that the work has always been faithfully done, but rather that lax inspection under existing political methods has failed to protect the interests of the public.

One of the most important qualifications of a society like this is the continuity of its work. Its individual members are mortal, but, so far as we can predict, there is no reason why the organization itself should not be perpetual.

Its success is based upon scientific facts. Its printed records now form, and will continue to form hereafter, a growing history of mechanical and scientific development. The compiling of history, interesting and important as it may be, does not appeal to the general public. It is the activity of the living present which attracts the attention of the multitude.

Phenomenal scientific discoveries, or epoch-making inventions, are exceedingly rare. Year after year a society must plod along, satisfied with thoroughly investigating each progressive step, and aiding in that gradual improvement which eventually brings about those grand results which are appreciated only when we halt for a moment, and review the progress of a decade or a century.

There is one exceedingly important duty voluntarily undertaken by societies which is of immense economic value. This is the introduction of standard practice in the particular field in which they are interested. Various individuals and manufacturing concerns, working along their own lines, gradually introduce products or methods, until with the growth of an industry there are certain differences established that finally become a well-recognized evil for which there is no apparent remedy. Finally, this state of affairs is seen to obstruct the attainment of the best results, or is even wasteful, by requiring the unnecessary expenditure of time, capital and labor. It is brought to the attention of a technical society through proper channels, and committees of experts are appointed, who industriously undertake to remedy or mitigate the evil. So thoroughly entrenched are existing practices, that the work of reform is beset with difficulties. In spite of these adverse conditions the project is carried through, and in some cases has received governmental sanction. Various organizations have taken up questions of this kind, and, while it is hardly possible to determine the exact benefits thus attained, there can be no doubt that great good has been accomplished. Among the examples that may be cited are "Standard Screw Threads," by the Franklin Institute; "Standard Boiler Tests," by the American Society of Mechanical Engineers; "Standard Steel Rail Sections," by the American Society of Civil Engineers, and, within the present year, the "Standardization of Electric Generators, Motors and Transformers," by the American Institute of Electrical Engineers.

It is gratifying to know that men of affairs, whose time is valuable, will so heartily devote themselves to the solution of the perplexing problems arising in the course of establishing standards of such a character that they will meet with the approbation of those who are expected to conform with them.

It should also be remembered that to the Franklin Institute should be given the credit for the organization under government auspices of the National Conference of Elec-

tricians in connection with the Electrical Exhibition at Philadelphia in 1884. The organization of the International Electrical Congress of 1893 was undertaken by the American Institute of Electrical Engineers, and the publication of its proceedings was carried out by the latter when otherwise its records would have been hidden from the world. This Congress established standards of nomenclature and of dynamic values and units which have been generally approved and recognized. There can be no doubt as to the public benefit arising from the existence of these organizations, but the carrying on of such work involves considerable expense, and this falls upon the members, many of whom feel that they receive no equivalent. This may be true within the limits of their past experience, but no one can tell what the future may bring forth. An item from a single contribution to the Transactions frequently is of more value to an engineer than the cost of many years of dues.

The first thing a young man should do in entering upon his professional career is to become a member of a society where he will come in personal contact with his fellow-workers. He should take a sufficiently active interest to show that he is not only capable, but ready to do his part in advancing the general welfare. He will soon find that it is not only a satisfaction to be identified with the organized membership, but that it will also be a direct advantage to him in many ways. Although the membership of a national society must necessarily be composed of those who are rivals in business or in the employ of competing companies, all antagonisms due to these conditions are laid aside in striving for the general progress of the profession. Institutions of this character enjoy a high standing in the community, and such work as appeals to public recognition is fully appreciated. There is still lacking, however, that continued interest in their routine work which its importance demands. While universities and colleges are handsomely endowed and suitable buildings erected for their use as memorial gifts, societies must levy on their supporting members to build or purchase houses, and ob-

tain their libraries in a similar manner, which are, nevertheless, frequently thrown open for public use.

Experience has shown that one of the most serious problems confronting a society of this character is the privilege of a proper meeting place, or, in other words, a suitable home. That the importance of such a building is fully recognized is shown by the efforts that are made to purchase one as soon as the revenue of a society becomes sufficient to warrant the expense. This is not an insurmountable difficulty in the case of national societies. The establishing of a home and library in the city which is selected for headquarters does not, however, meet the requirements of the entire country. In every city there is a sufficient number of men interested in scientific and engineering questions to form local societies or clubs which would be of great public value in the administration, for instance, of municipal affairs. It is in such towns that the lack of a suitable meeting place or the expense of maintaining one interferes with the formation of technical organizations. Their existence is not considered a public necessity, yet, when important municipal improvements are projected, there could be no more satisfactory discussion of the problems to be considered than would be elicited from a body of this kind. It would differ from a town meeting in several important respects. Each member would be trained to view the questions from a scientific standpoint. He would not be influenced by the political aspects of the case. He would base his opinions on the experience of others, and he would be familiar with the record of that experience or he would know at once where he could refer to it.

Having been assigned the duty of pointing out the advantages occurring from the existence of such organizations as the Franklin Institute, whose seventy-fifth anniversary we have gathered to celebrate, I have gone a little further and intimated that they might be still more useful if the people generally were closer in touch with their proceedings. They are really supplemental to our educational system. The fact is generally recognized that no matter how high may be the standing of a college graduate, his education in the

school of experience ends only with his life. It is through these societies that the results of personal professional efforts are gathered and recorded. His thoughts are brightened, his best work is studied and appreciated by his colleagues. He is stimulated by healthy rivalry to do his best, and to honor the achievements of others.

We need have no apprehension as to the future of our great technical societies. There are the best of reasons for their continued existence and their healthy growth. Their foundations are deeply embedded and beyond the reach of those discordant elements which frequently revolutionize governments, divide our churches and overthrow the greatest financial undertakings.

THE FRANKLIN INSTITUTE.

Stated Meeting, Wednesday, February 15, 1899.

THE PHOTOMETRY OF INCANDESCENT LAMPS.

A SPECIAL PLAN FOR READILY PROCURING RESULTS, AND THE APPARATUS NECESSARY FOR THE PURPOSE.

BY PROF. ARTHUR J. ROWLAND,
Member of the Institute.

In the industrial photometry of incandescent lamps, one of two things is always the object of measurement, *i. e.*, the candle-power which an incandescent lamp has at any applied E.M.F., or the E.M.F. which should be applied to produce a given candle-power. The first is the one with which users of lamps have to do; the last is a determination which the manufacturer of incandescent lamps has to make for his whole product. Strange as it may seem, the last is much the harder to obtain if ordinary photometric methods are used.

There are many sorts of photometers and many methods of using them. What I shall say will have reference to but

one sort, a Bunsen photometer, and to a certain plan of using one which makes it especially easy to work with.

A Bunsen photometer is a familiar instrument. In its simplest form it consists of a graduated bar, at the ends of which are located the lights to be compared, one of them being of known candle-power. Along the bar one moves the car, which holds, in a plane perpendicular to a line joining the lights in question, a paper with a grease spot on it. When a position is reached where the spot cannot be distinguished from the surrounding paper, one knows that the illumination of both sides of the sheet is alike; that is, since the illumination of a surface falls off with the square of the distance from the light source, by taking ratios of distances to lights from the car position squared, one has obtained the ratio of the candle-power of the lights.

In practice one has many obstacles to overcome in getting this simple result. In matters photometric there are such as:

(*a*) Too large a ratio between the candle-power of the light measured and that of the standard light. This causes a slight inaccuracy in the setting of the car to make a very disproportionate inaccuracy in the resulting candle-power calculated.

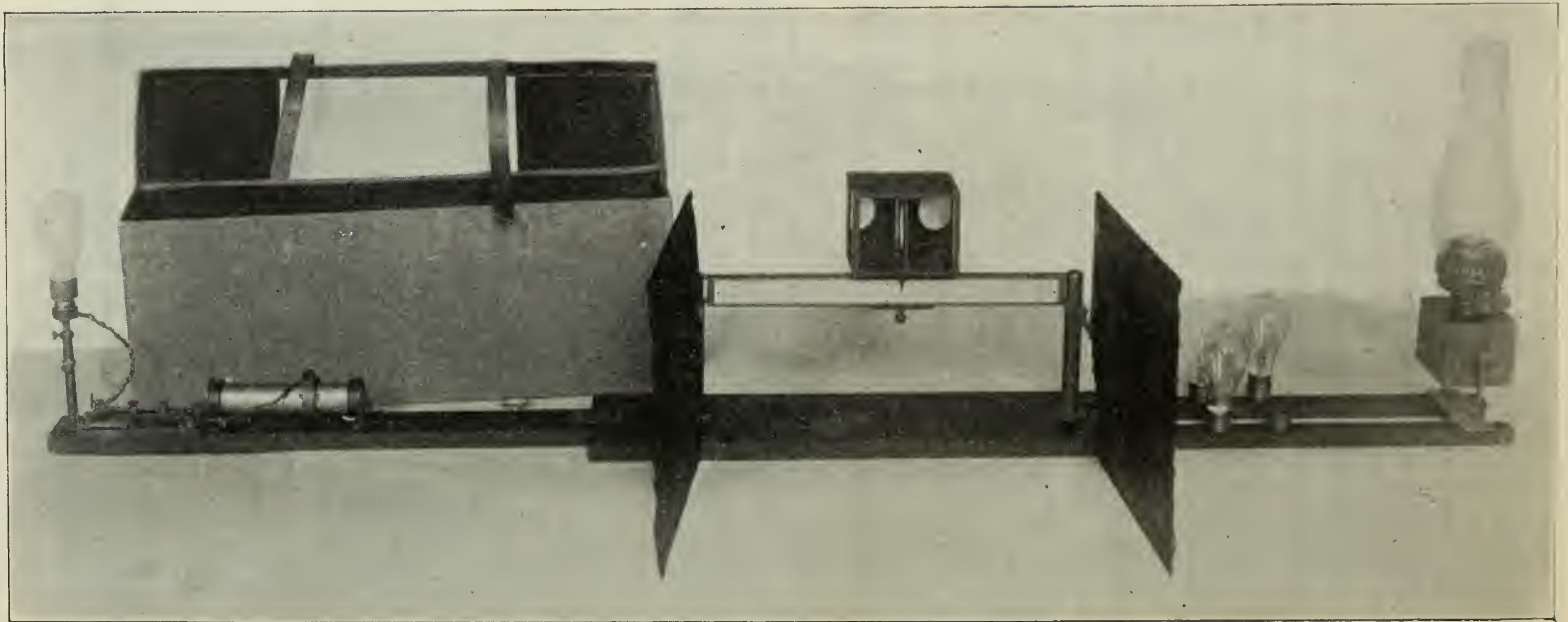
(*b*) A difference in the color of the lights which are being compared. This makes it impossible to find a place along the bar where the grease spot disappears.

(*c*) Reflection from surrounding objects. A distortion of the illumination of the paper in the car results, so no *true* ratio can be found.

(*d*) A difference in the quality of the sides of the paper with the grease spot on it. If the paper be turned side for side, quite a different setting of the car for "equal illumination" will be found.

(*e*) A difference in eye-sensitiveness. If one stood on the other side of the bar a different determination would have been had.

(*f*) A difference in mirrors used to enable one to see both sides of the paper at the same time, and so distortions, similar to those last mentioned, are produced.



A D F C F E B

FIG. 1.—The photometer set up ready for use.

In matters of manipulation there is the difficulty in keeping the E.M.F. on the lamps steady; in adjusting the E.M.F. within very close limits; in knowing the exact E.M.F. sending current through the lamp, due to the inaccuracy of voltmeters which have not been especially calibrated for the work. Any of these not right and errors in the results are found, so they become utterly unsatisfactory and unreliable. An inexperience in making readings or poor choice of conditions causes results to be procured which are equally valueless.

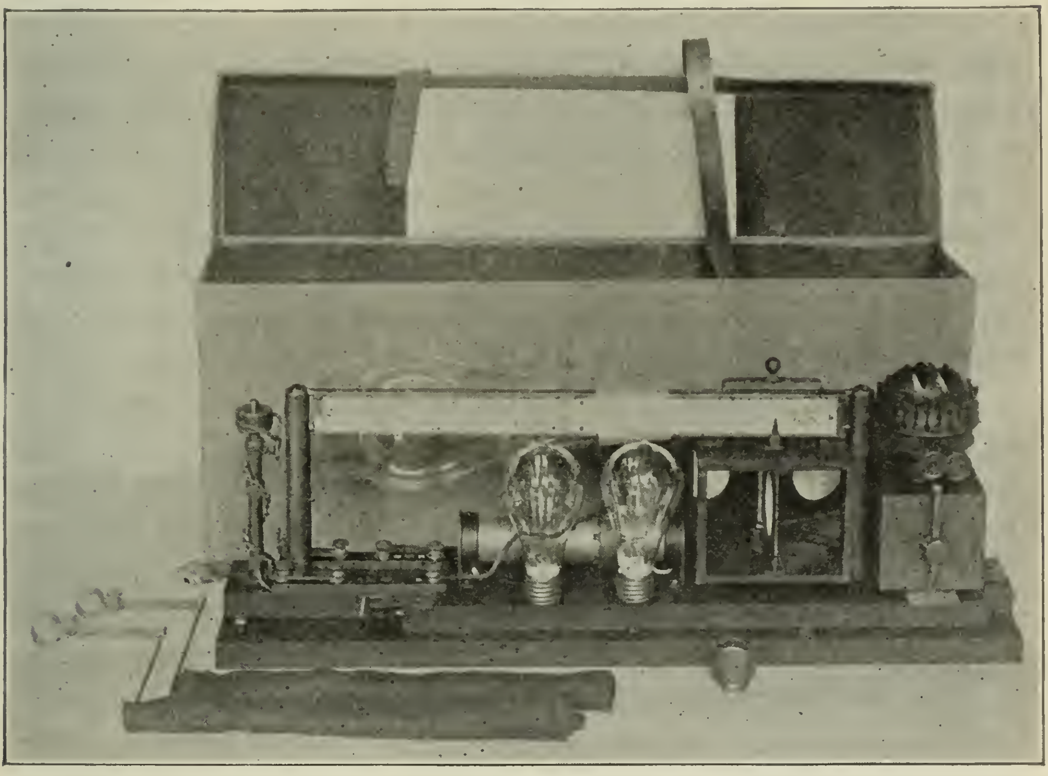


FIG. 2.—The photometer folded and ready to put into its carrying case.

In getting results in the usual way one has to labor through the tedious process of taking ratios of distances which must be squared, and must take enough readings to eliminate errors already mentioned by taking averages of candle-powers determined from a number of car settings.

So many of the difficulties are met and mastered in a portable photometer which has been loaned me by the Electric Motor and Equipment Company, Newark, N. J.,

that I will use it as a text in considering the special method of measurement I want to describe. In this photometer a grease spot car is used, and the standard is an 8 candle-power oil lamp, which practice shows to be of more than required constancy over a period of twenty minutes or more at a time.

Fig. 1 shows this photometer ready for use. The different parts may be described by reference to letters placed directly below them in the cut. At *A* is put the incandescent lamp whose candle-power is to be determined. Provision is made on each photometer for lamps having Edison, Westinghouse or Thomson-Houston bases. *Fig. 2* shows this detail better, one of the interchangeable parts for altering the style of the socket being shown on the table just in front of the packed photometer and to the right of the center of the cut. At *B*, at the other end of the instrument, some five feet from *A*, is the oil lamp. This holds enough oil to burn for four hours in use, and for an hour at a time with practically no change in its candle-power after once warming up and being set.

Since the standard is of fixed value, a direct reading scale can be used. It is shown directly below the car at *C*, and is marked off on celluloid from 7 candle-power to 34, marks being made for each half candle-power. In the car one can see the screen with grease spot, and the reflections of the two sides of the paper in the mirrors. The index for reading candle-power at any car setting shows on the scale just under the grease spot.

The screens, *F F*, are to shield the eyes of the observer from direct light from either source. His eyes must be protected thus so they may be adapted to distinguish small differences in tint of spot and field as he views the reflections in the mirrors. This arrangement makes "taking readings" much less fatiguing than the common and older plan of using an eye screen fast to the car, such as is used with fluoroscopes.

At *E* is a rack to hold the standard lights. They are here out of the way, and yet conveniently placed to carry about or use.

A very refined adjustment of the E.M.F. on the lamp terminals is provided for by the rheostat shown at *D*. This is a solenoid of resistance wire along which a contact piece is arranged to be moved, so varying the E.M.F. on a 16 candle-power lamp through a range of 15 or 20 volts by steps so small as not possible to detect with a first-class voltmeter. Thus one has at command the adjustment of the E.M.F. on the lamp under test to the exact value required, and a cause of errors of considerable magnitude is eliminated. At its marked E.M.F. a 16 candle-power 110 volt lamp will vary in candle-power as much as 6½ per cent. for a 1 per cent. change in E.M.F. applied, it must be remembered.

Between the incandescent lamp and rheostat there are some simple switching devices provided, and the connecting cords to use at them to bring current to the photometer and to connect voltmeter, ammeter, wattmeter or all of them at once to the circuit, as one chooses.

The 8 candle-power oil lamp is set to the value it must keep through a set of readings in a fashion which at once eliminates nearly all the difficulties in making satisfactory photometer measurements, which I have mentioned. The method of proceeding to a candle-power measurement is as follows: The oil lamp is lighted and warmed up. A standard incandescent lamp at an E.M.F. about like that on the circuit to be used is put in its "standard position" (that for which its candle-power is known), and its terminal difference of potential made that demanded on its label. It is now 16 candle-power from a direction down the photometer bar. The car is next set at the 16 candle-power mark and the light from the oil lamp adjusted until the grease spot disappears. The standard incandescent lamp is next removed and others, whose candle-power it is required to know, put in its place, one after the other, the car being shifted to a point where the grease spot disappears for each one, and their candle-power thus read directly. After a little practice one can make such readings on a 16 candle-power lamp so that the widest range of values determined will not be more than $\frac{4}{10}$ of a candle-power. And if all are

averaged, no reading differs from this value by more than $\frac{2}{10}$ of a candle-power. In other words, an accuracy in a single reading will be within $1\frac{1}{2}$ per cent. of the truth. This is a very satisfactory result for a determination of candle-power on a commercial photometer. It is to be understood as applying to readings made at different times upon the same lamp.

Or, for other purposes, the car is left at 16 candle-power, for example, and the E.M.F. on the lamp varied until the spot is gone. The determination of this last can be made by a practised observer with quite remarkable accuracy, considering the shortness of the bar.

The oil-lamp standard can be checked at any instant by a return to the incandescent standard at the other end of the bar, setting the index on the car at the 16 candle-power mark and observing whether the grease spot is now invisible, as it should be.

Without going into a detailed explanation, one has, by this method, done away with all difficulty due to reflection, difference in quality of the sides of the greased paper, difference of eye-sensitiveness, etc., and done away with them all to such an extent that a real dark room is not required to get satisfactory results. If only the light is not shining in the observer's eyes, a room not so dark but that common newspaper print can be read in it is satisfactory for ordinary work. By putting the real standard at the same end as the lamp whose candle-power is measured, all distortions come into every measurement in exactly the same way, and so are negligible. I am not informed whether or not this plan of working is original with the company above named, but it is certainly a plan of greatest possible value to any one who has many measurements of candle-power to make, and wants them procured in as rapid and yet accurate a way as possible.

It will be seen that really the candle-power of the oil lamp never becomes known. It is simply a steady light, the value in candle-power of which need not concern one.

The oil-lamp flame is not noticeably different in color from many incandescent lamp filaments, especially if the

incandescent lamps are not perfectly new and burning at high incandescence; and, by using it, rather than a second incandescent lamp, one does away with the necessity for a second voltmeter and its separate and accurate calibration.

It cannot be denied that, if there are incandescent lamps at both ends of the bar, having the same efficiency and candle-power, any fluctuations of E.M.F. on the circuit after that on both lamps has been set will not interfere with the candle-power determinations, since the ratio of candle-powers will keep the same. But any advantage so obtained is more than offset in most commercial work by the necessity of having voltmeters for both lamps, and accurate ones, too.

Since the photometer I am using to illustrate these remarks is a portable one, it lacks certain accessories, like a rotating socket, by the use of which the mean horizontal or rated candle-power becomes known at once.

Fig. 2 shows the instrument packed and ready to be put in its carrying case, shown in the background. There is no question as to the exceeding portability of the instrument, not only because it can be used without a dark room, but also because it can be put together so compactly to carry around.

Considering the purpose for which it was designed, therefore one can forgive the lack of a rotating socket.

I have described the instrument, not because it is a perfect one for *all* requirements of up-to-date photometry, but because it seems to me, a disinterested party, to embody very many points which must make a commercial photometer a satisfactory instrument, and so to be worthy of presentation to the members of the Institute.

On the GRAPHICAL PRESENTATION of STATISTICS.

By Lewis M. Haupt,
Member of the Institute.

While statistics are said to be uninteresting, they are, nevertheless, invaluable as indices to the progressive man of affairs who would keep in touch with the industrial development of his own or other countries. But masses of figures arranged in tabular form are confusing and often misleading, without great labor in classifying or in reducing them to units of comparison. Frequently only total quantities or values are given of imports, exports, output, product or prices, rendering a large amount of calculation necessary before unit values or percentages for various years, periods or commodities may be secured, and without which no comparison is possible.

To show the growth of any particular industry, it is evident that at least two factors must be represented, viz., time and quantity, or time and value. When all three are known, and the totals only are given, they must be reduced to the value of the unit for each time stated, to determine the actual returns. Since quantity may be expressed in many different denominations, as in pounds, tons, yards, bushels, bales, barrels, stones, cords, etc., they must also be brought to a common basis for comparison.

To avoid many of these difficulties, the practice of representing statistics by the aid of diagrams, plain, colored or shaded in conventional symbols, is rapidly growing in favor, but the existing conventions possess defects which render them almost useless as bases of comparison for commercial purposes, unless accompanied by abstract figures, in which case the former objections are not eliminated.

THE EXISTING DEFECTS.

For example, in comparing quantities of any particular kind, as of population, a column is built up of colored blocks having three dimensions, requiring the eye to

compare these volumes with one another. Often they are not even similar volumes, so that the cubes of their edges cannot be used for the purpose intended, and unless the figures be branded on the blocks, no idea can be obtained of even their relative volumes. In many other cases areas of various forms and sizes are used, especially rectangles and circles, but frequently sectors are employed in circles of different diameters, to indicate growth from year to year. Here, again, figures of two dimensions are therefore erroneously used to represent quantities of only one dimension. It is true that the circumference of the circle may be subdivided into arcs, representing proportional parts or percentages of traffic or product, but unless the ratios are indicated in the degrees of the central angle, or the relative lengths of arc, the sectors possess but little actual value for comparison.

Even where statistics are represented in columnar form, laid off on both sides of a central axis, the curve of increase is bisected, one-half of it being on either side of the axis, and, therefore, the correct curve is not shown on the diagram, but must be deduced from it by a mental operation.

Again, it frequently happens that the intervals of time when the record is made are quite variable, so that without interpolation a correct idea of the form of the curve cannot be obtained even with the abstract figures stated. Certainly the rectangles drawn to scale, unless taken in connection with their time intervals, become quite misleading. The absence of uniform scales, and the omission of any reference thereto, results in representing the parts as sometimes greater than the whole, a manifest absurdity.

These and many other incongruities arise from the promiscuous pictorial methods in vogue intended to educate the mind by unscientific, popular methods, resulting in "confusion worse confounded."

SUGGESTIONS FOR GENERAL USE.

All quantities, of whatever denomination, kind or extent, which are capable of being measured, may be expressed in abstract figures, and such figures may always be repre-

sented by linear distances drawn to scale by taking any number of such parts as a unit. As the number representing the quantity or price may vary from time to time, so the lengths of the lines will vary for the corresponding times, and these lines may, therefore, be compared, and the ratio of any one to any other be determined by projecting them upon a sheet of cross-section paper, starting always from a straight line or edge.

Thus, if the law of the increment of any variable quantity is to be represented, the times at which the variations occur may be laid off along a straight line, while the actual value of the variation may be platted in a series of lines at right angles to the first, constituting a system of rectilinear coördinates, of which the times may be the abscissa (x) and the quantities the ordinates (y). By drawing a line through the extremity of the ordinates, the curve showing the change in value of the quantity is at once revealed.

If the increments for equal times are equal, the curve will become a right line, and a prediction can safely be made as to future probabilities. If it bend upward, the increments are increasing; if downward, decreasing. They may oscillate violently, indicating lack of stability or great fluctuations in value, generally traced to some external cause affecting the value of the commodity used in exchanges, as a plethoric or stringent money market, abundance or paucity of crops, etc.

TO ILLUSTRATE DEVELOPMENTS.

The resulting diagrams, if platted as indicated above, will give a simple, accurate exhibit of the conditions existing at any particular date, whence they may readily be connected with correlative events, and the relation between cause and effect be largely determined with accuracy. As population is the basis for, and principal element in, industrial development, and as it is important to determine the probable increase as affecting questions of consumption or traffic, it may be instructive to illustrate the above method by platting the curve of the growth of population during the past century in the United States. Thus, on the diagram, it will

be seen that the axis of X is horizontal, having a scale of ten years to 1 inch, while that of Y is vertical, having a scale of 10,000,000 to an inch. (See *Plate I.*)

Taking the origin of coördinates at O, and the data from the census reports for each decade, beginning with 1790, it will be seen that the curve at first departs but slightly from the horizontal axis, but gradually increases its flexure upwards and must, in course of time, approach a tangent to the vertical, becoming, in short, an asymptote—this, too, notwithstanding the fact that the *percentage* of increase decreases from the beginning to the end of the century.

It is thus shown at once that the increment is not a simple ratio, as in an arithmetical progression, but is being compounded each decade. Hence it is that the population under normal conditions increases more rapidly each decade, although the percentage may decrease. Between 1790 and 1890, for instance, the population increased 1,491 per cent., or 14·91 per cent. on an average each year, if computed as simple interest upon the original principal. Yet the rate each decade before the civil war was varied from 33 to 36 per cent., or only $3\frac{1}{3}$ to $3\frac{2}{3}$ per cent. per annum.

During the war decade it was only 23 per cent., increasing to 30, and again decreasing during the last decade to 25 per cent.

The actual increments of population, however, were nearly 12,500,000 in 1880–90, as compared with less than 2,000,000 in 1800–10, when it was 36 per cent. of the whole.

What this rapid or compound increment portends in the near future for the trade prestige and influence of this nation may be more clearly understood by extending the curve at the constant ratio of that of the past decade, namely, 25 per cent., from which it appears that the population of 1890 will have doubled itself by 1920, or in thirty years, and by 1950, it will have again nearly doubled if the ratio remain constant and the government stable and liberal.

It is not to be expected, however, that the ratio will remain constant for so long a period, but it will not be many years before our population will reach 150,000,000 souls.

TO REPRESENT VARIATIONS.

Fluctuations in values may also be illustrated most forcibly by the use of the graphical method.

Take, for example, the relative values of gold and silver during the past century, and plat the curve of their ratios as per the diagram (see *Plate II*), and it will reveal at a glance the relation between the values of those commodities and legislation. The stability of their relative values, from the close of the last century, through three wars and several financial crises, up to 1873, the year of the passage of the demonetization act, is clearly shown, as well as the effects on the ratio due to subsequent acts. This diagram, therefore, is a sharply-defined representation of the fact that the value of silver as a medium of trade has depreciated rapidly, while that of gold has as rapidly appreciated, neither being stable nor a "standard," and, but for the providential development of large deposits and the reduction in the cost of extraction of gold, the discrepancies in values would have been much greater.

TO DETERMINE FRANCHISES.

Columns of figures are also confusing when it is desired to determine the values of a franchise from the tabulated annual revenues of any enterprise, and an average of the net returns is also misleading, since the profits will generally be less during the earlier stages of development than in the later year. Here, again, the superiority of the graphical curves plays an important part in revealing at once the actual condition of affairs.

To illustrate: take the case of the Monongahela River Improvement from 1840 to 1896, and plat the receipts and expenses, as shown in *Plate III*. These curves indicate readily the fluctuations due to internal and external causes far better than can be done by an array of figures. If a dam breaks, the expense account goes up and the revenues down; if enlargements or betterments are added, the operating expenses reach a higher plane, while the revenues are correspondingly increased.

But probably the most practical use of this diagram is

PLATE II.—CURVE SHOWING EFFECTS OF LEGISLATION ON RELATIVE VALUES OF GOLD AND SILVER.

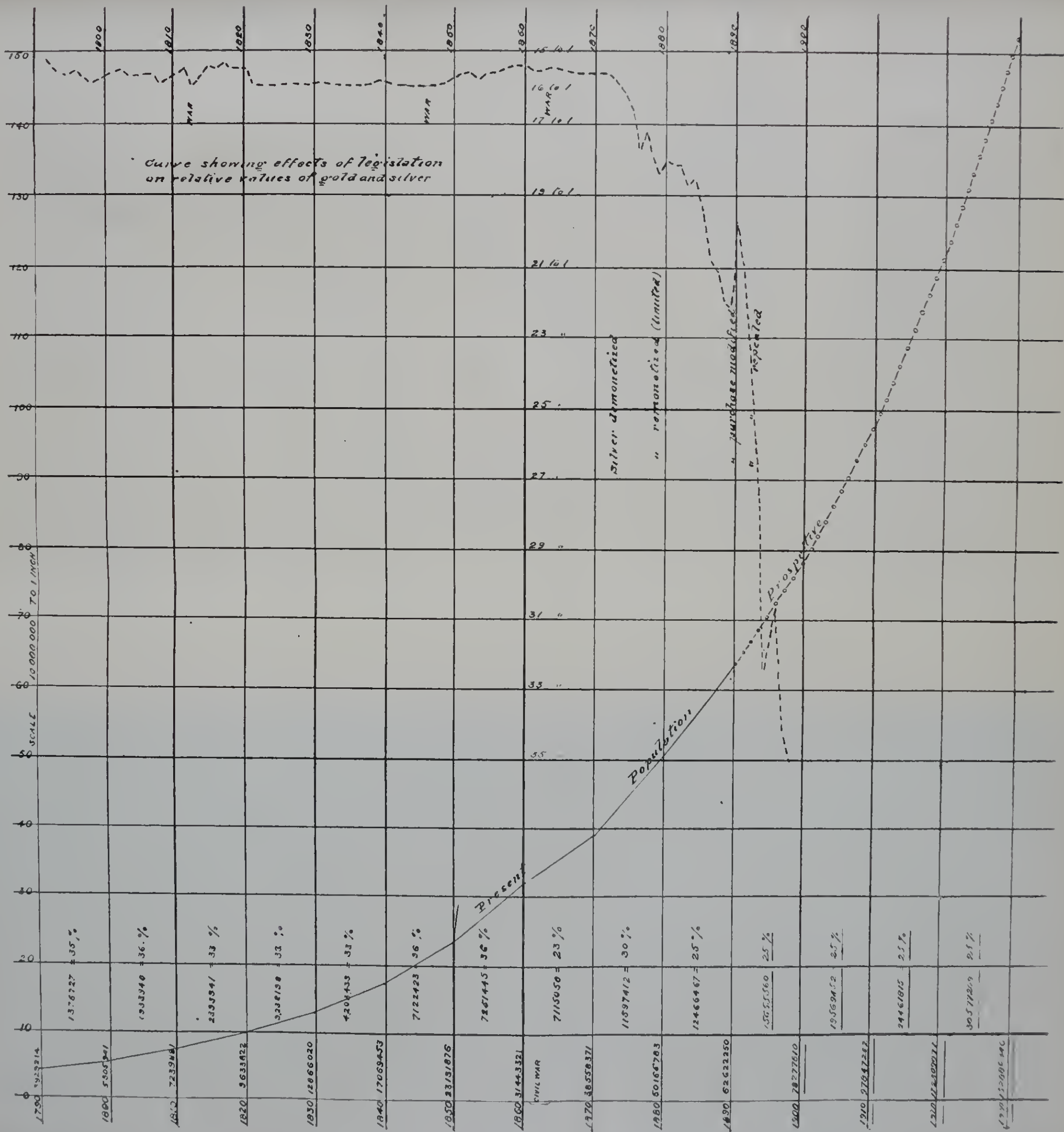


PLATE I.—CURVE SHOWING GRAPHICALLY THE INCREMENTS OF POPULATION

to determine the value of the company's franchise by the establishment of the average financial gradient. This is done, approximately at first, by a trial line with an assumed annual increment, and by then taking the algebraic sum of the ordinates of the revenue above and below this line. If

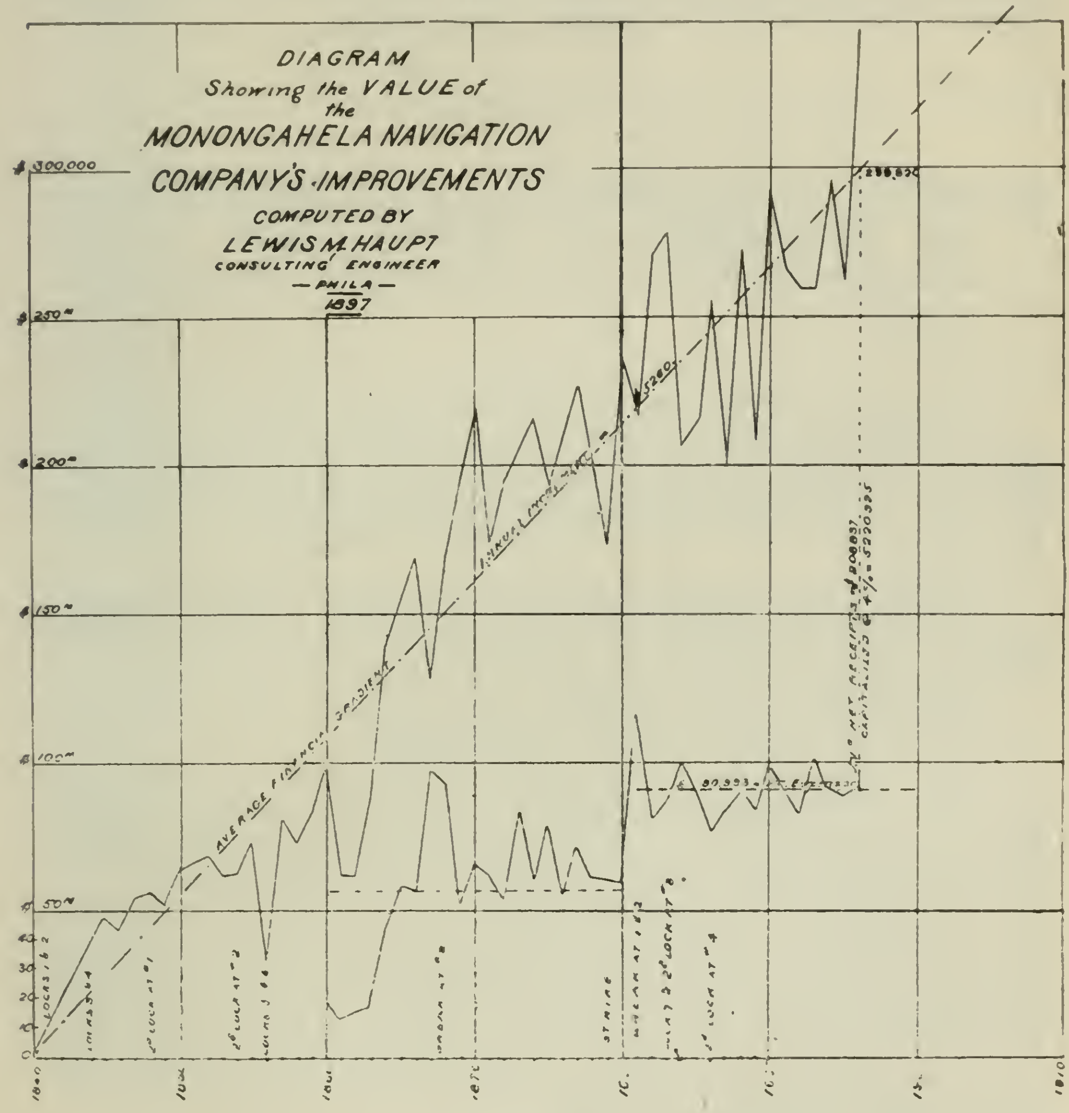


PLATE III.

this sum is not equal to zero, it should be further adjusted until it is so, when the true line becomes known. By capitalizing this increment at the current rate per cent., the value of the franchise is readily found.

These few illustrations will serve, it is hoped, to estab-

lish the great superiority of the linear methods of representing statistics as compared with the pictorial volumes and areas, which are almost useless to the statistician as well as to the public. If this brief article will aid in eliminating so unsatisfactory a method, and in substituting therefor the general use of the more scientific and accepted projections, it will have served its purpose.

SUMMARY OF THE REPORT OF THE COMMISSION ON THE EXTENSION AND IMPROVEMENT OF THE WATER SUPPLY OF THE CITY OF PHILADELPHIA.

Following is a summary of the conclusions presented in the report of Messrs. Rudolph Hering, Samuel M. Gray and Joseph M. Wilson, the experts named by the Mayor of the city of Philadelphia, with the consent of the Councils, to examine and report upon the questions involved in providing for the urgent requirements of the city in connection with its present and future water supply :

"The deplorable condition of the city's water supply, which it is sought to remedy, is due to the pollution of its sources, to the lack of effective pumping machinery, and to the insufficient capacity of the distributing system.

"The question of first importance is the source of supply, and to this nearly all of our thought and time has been devoted.

"Most of the water is now obtained from the Schuylkill River, within the city limits. Five pumping stations take from it about 200,000,000 gallons daily. One pumping station is located on the tidal estuary of the Delaware River at Lardner's Point, and supplies about 15,000,000 gallons daily.

"The Schuylkill water is being polluted at many points from its source down to the city line. Beginning with the mine waters, the coal dust and some sewage from the upper parts of the water shed, the pollution is increased below by the sewage of cities and villages situated along the river and its chief tributaries, by the manufacturing refuse and by the surface water from agricultural districts, all of which render the water sometimes turbid, unpalatable, impure and dangerous to health.

"The Delaware water at Lardner's Point is less turbid after rains than the Schuylkill water ; it is also softer and less polluted. Its flow is many times larger. While this water is, therefore, now somewhat better than the Schuylkill water, the growth of the city, the newly-built or projected sewers above and below the intake, and the tidal oscillation of the water, tend to a continually increasing pollution also of the water taken from the Delaware River.

"It, therefore, becomes imperative either to select a new source of supply or to improve the present one, so that it will become thoroughly satisfactory

to the citizens both as to quality and quantity. The first project requires the bringing of Blue Mountain water to the city; the second requires a thorough filtration of the Schuylkill and Delaware waters taken within the city limits. A decision as to which of these alternative projects is the better one must be based on the quality and quantity of water to be supplied and on the cost.

"It was, therefore, necessary first to make certain preliminary assumptions, then to make designs for both projects, and to ascertain the cost of construction and operation. The assumptions as to population and as to quality and quantity of water are as follows:

"The present population, to be supplied from the city's pipe system as soon as practicable, is taken at 1,300,000 persons. The population to be held in view in the design for new works is assumed at 3,000,000 persons.

"It was considered that the waters collected from the affluents of the Delaware and Lehigh Rivers in the Blue Mountains, and from the Upper Perkiomen Creek, could be used in their natural condition. While these natural sources are the best obtainable at a reasonable cost, and while their average standard of purity is high, it must be remembered that a guarantee against an occasional and temporary pollution of the water by disease germs from man and animals cannot be given for such large and exposed water sheds. Nor can an occasional taste, due to vegetal matter, be entirely avoided.

"The alternative source of supply is the water of the Schuylkill and Delaware Rivers, within or near the city limits, artificially purified to the required standard. The purification is obtained by filtering the water through sand: no better and cheaper method is known.

"The progress made in this country and in Europe in ascertaining the laws of the mechanical and biological process of filtration, and the practical success obtained in filtering water for many years in large cities of Europe, confirm and warrant the conclusion that this method of purification can furnish this city, from both rivers, with water that will be clear and palatable, and will conform to the best bacterial and chemical standards.

"When the raw river water carries much suspended matter with it, this must be allowed to subside, as a preliminary to filtration, so as to lengthen as much as practicable the time between the filter cleanings. Settling reservoirs are, therefore, essential as preliminaries to the filtration of the water of these two rivers. In order to secure the greatest practicable efficiency, the filter plant must not only be built with skill, and be provided with the best means for regulating the flow, and for cleaning the sand, but it must also be carefully operated by trained men, in accordance with the daily condition of the river water and of the filters.

"The quantity of water required for city consumption depends on local conditions. In some cities much less water is used than in others. The quantity with which Philadelphia has generally been credited is somewhat misleading, due to the absence of proper measuring appliances; as a matter of fact, it is less than appears on the records. There is also in this city an undoubted waste of water, the amount of which cannot now be accurately determined, and which confers no benefit whatever, either to persons or property, or for street or sewer cleaning. It therefore subjects the citizens at large to an entirely useless expenditure, which should be stopped at the earliest practicable moment.

"We consider that at present a daily supply of 200,000,000 gallons, being 150 gallons per capita, is a very liberal allowance. We recommend that this quantity of pure water be immediately provided for. At the same rate a population of 3,000,000 persons will require a daily supply of 450,000,000 gallons.

"Comparative estimates of cost have been made for eventually supplying these quantities. In order to indicate the legitimate outcome of an extravagant use of water, we have made a further estimate of cost for supplying the city daily with 700,000,000 gallons of mountain waters.

"The Blue Mountain water projects deliver water to the city reservoirs by gravity. In one, mountain water is obtained from the upper Perkiomen Creek and from the Lehigh River, with its tributaries. In another, mountain water is taken from the Delaware tributaries near the Water Gap. Still another project was considered, using the Delaware water at Portland, below the Water Gap, but after filtration. Other projects were considered, but were found to possess no special advantages, and were also more expensive.

"The filtered water project which has been specially considered is confined to taking water from the Schuylkill and Delaware Rivers within the city limits.

"Two methods of filtration are in common use ; one allows the water to percolate slowly through a bed of sand, while the other allows it to pass through much more rapidly, and, in order to give it the same degree of purity, requires the use of a coagulating substance to prevent objectionable organisms and suspended matter from passing through the filter. The first we have called a slow and the second a rapid filtration.

"Inasmuch as it has been impossible, in the time at our disposal, to make the necessary experiments showing the precise effects of filtering both the Schuylkill and Delaware waters, either through slow or rapid filters, it is also impossible now to state which of the two systems would be the more economical. But we know, and can positively assert, from experience obtained elsewhere, that, for the plants which we have recommended, a slow filter system will not materially differ in annual expense from a rapid filter system We likewise know that the slow filters, from long experience, and from their successful operation in many cities, can, without question, yield satisfactory results with the waters of the above-mentioned rivers. The rapid filters have only recently been sufficiently developed to command a high degree of confidence in their results under all circumstances.

"We are of the opinion that for the present supply slow filters should be adopted at every station in the city, excepting at the one near East Park reservoir. We believe that at the latter station a rapid filter plant would be more serviceable.

"A comparison of the estimates of cost shows the following results :

"The most economical project for a supply of mountain water is that taken from the upper Perkiomen and from the Lehigh water sheds. For immediate needs, its cost of construction is $33,410,000. Its annual cost for operation, interest on investment, and all expenses, to deliver the water into the city reservoirs is $1,205,000.

"For a daily supply of 450,000,000 gallons, the total first cost would be $66,740,000, and the annual cost, $2,480,000.

"The most economical project for a supply of filtered water is that by which the waters of the Schuylkill and Delaware Rivers are filtered within the city limits. cost o construction, for present requirements, would be $10,974,000. Its nnua cost for operation, interest and all other expenses, to deliver the water into the city reservoirs is $1,227,000.

"For a daily supply of 450,000,000 gallons, the total cost of the filter plant, including special mains from Torresdale to the center of the city, would be $34,155,000, and the annual cost, $2,972,000.

"The estimates of cost have shown three important results:

"(1) The original cost of any of the mountain water supplies is very great for the large quantities of water which the city requires

"(2) A filtered water supply can be obtained at a first cost which is within the present borrowing capacity of the city, and the plant can be operated at a cost which will not exceed the probable annual net earnings of the water works.

"(3) The total annual cost of delivering the water into the city reservoirs, by either method, is about the same, and the annual earnings will cover the operation and extension.

"In conclusion, we recommend:

"(1) The adoption of that project by which the waters of the Schuylkill and Delaware Rivers, taken within the city limits, are purified by filtration.

"(2) The immediate improvement of the existing plant, in accordance with the detailed recommendations of our report.

"The necessity for the second of these recommendations is manifest. Our reasons for the first are as follows:

"The entire works can be built for a sum which the city can secure at this time through a loan.

"A supply of pure water for the entire city can be obtained within a comparatively short time, and the city can thus at an early day be protected against a continuance of those diseases which are known to be caused by the present polluted water supply.

"A filtered water supply, under skilful management, offers a greater security against the effects of accidental pollution of the water than is possible when the supply is taken from open, unprotected watercourses. Filtration can, without difficulty, be made to render the water thoroughly wholesome.

"The two large rivers at Philadelphia, or even the Delaware River alone, can furnish at all times a quantity of water sufficient for a very large city."

Upon the subject of "Filtered Water Supplies" the experts outline the prospective plan of supply for this city in the event of the adoption of the plan agreed upon as most desirable and approved by the Mayor. The report says:

"The slow filters are all designed for an average rate of 3,000,000 gallons of water per acre of effective area (about 9 cubic feet per square foot) per day. The number of filter beds erected at each site at first would be only for present demands, and each plant could be increased thereafter from time to time, as found necessary, by additional filter beds, ample ground having been reserved for this purpose, except in the case of the Queen Lane.

"The area available for slow filters at Queen Lane is limited, so that pro-

vision cannot be made at that site to filter more than 58,000,000 gallons per day, although the amount used in that district will hereafter be considerably greater. This deficiency will be made up from East Park, and for that purpose high-service pumps at East Park will be required.

"A rapid filter plant has been adopted at East Park.

"In considering the Schuylkill and Delaware Rivers as sources of supply to be filtered for the city, we have decided upon the following main points:

"(*a*) To utilize and adopt the present plants as far as possible and to the best advantage.

"(*b*) To use the Schuylkill water for the districts of Belmont, Roxborough and Queen Lane, with such surplus as may remain of the limited 150,000,000 gallons supply per day for East Park.

"(*c*) To abandon the reservoir at Fairmount, which is now in use only for about seven months in the year, and to connect the turbine pumps with Spring Garden station, so that they may be placed in service whenever the supply of water will allow, thereby relieving the steam plant of a corresponding amount of work.

"(*d*) To abandon the Corinthian reservoir.

"(*e*) To retain the Fairhill reservoir, which, although not now designated for use, will hereafter undoubtedly be found valuable as a center of distribution for filtered water, and can be so adapted by modification and covering.

"(*f*) To adopt slow filtration for Belmont, Roxborough and Queen Lane districts, and rapid filtration for such remaining portion of the Schuylkill water as is delivered at East Park.

"(*g*) To establish a slow-filter plant on the Delaware River, below Torresdale, from which all the water not supplied from the Schuylkill will be obtained.

"(*h*) To make use of the present reservoirs, whenever possible, for sedimentation and for the storage of filtered water.

"(*j*) To allow at least twenty-four hours for sedimentation, and to provide storage capacity for one-half day's supply of filtered water.

"(*k*) To cover all storage reservoirs for filtered water.

"(*l*) To cover all filters.

"It is, of course, eminently desirable that the water supplies for filtration should be as free from impurities as possible, so as to reduce to a minimum the duty on the filters; and every effort should be made, by legislation and otherwise, to prevent the pollution of streams; yet such water as exists to-day, in the Schuylkill and Delaware Rivers at the city of Philadelphia, can be purified by filtration and rendered wholesome and fit for all domestic purposes.

"Within the city limits it is possible to locate the filter plants at places where the water supplied to them will not be subject to direct sewage pollution. A point can be selected on the Delaware River within the city limits, but above such direct contamination, and the present intakes on the Schuylkill are well situated in this respect. The locations and conditions of existing pumping stations and reservoirs are such that it is advisable to continue the use of the water in this river up to a quantity equal to its minimum flow, at least so long as the present plant can be made serviceable. For additional supply, and for future extensions, the Delaware is the proper source, and in time it is not impossible that the whole supply may come from that river.

"In order to ascertain the suitability of certain sands, obtainable in the vicinity of Philadelphia, for use in filter plants, we have had mechanical analyses made of a number of samples. The results which are given indicate that there will be no difficulty in obtaining suitable material for the purpose.

"If the annual rates remain the same, the surplus earnings of the Bureau of Water would, to all appearances, be sufficient to pay for the continual extension of the plant as required by the growth of the city.

"Owing to the improvements constantly being made in the operation of filtration plants, it is probable that our estimated cost of filtration will be found, in the future, to have been too high, rather than too low.

"It will be noticed that the estimated cost of filtering on the Delaware is slightly less than on the Schuylkill.

"When the present reservoirs are converted into settling reservoirs for use prior to the filtration of the water, it will be necessary, in some instances, to readjust the water intakes and outlets, so as to accomplish the highest possible degree of sedimentation during the time that the water is passing through the reservoir.

"It is advisable that filters and clear water reservoirs be covered or roofed, to prevent the formation of ice on the surface and to protect the filtered water from pollution by the dust in the air, which carries the seeds of lower life. There is abundant evidence of the deterioration of filtered water or of spring water kept in open reservoirs. In covered reservoirs the water is also cooler in summer than when exposed to sunlight. There is an erroneous idea that sunlight and air are advantageous to stored water. The contrary has been frequently demonstrated, and every one appreciates the excellence of spring water, which issues, so to speak, from the bottom of a large natural filter, without having been exposed to either sunlight or air. There are both chemical and biological reasons for these facts.

"The slow filter plants contemplated in our recommendations are similar, in general arrangement, to those of London and of Hamburg, and to the recently completed filter plant at Albany, N. Y. The latter is the largest filtration plant in this country.

"We have said that we consider it inadvisable during dry years to obtain a greater amount of water from the Schuylkill River than 150,000,000 gallons per day. A provision for supplying the city with 200,000,000 gallons daily, therefore, requires 50,000,000 gallons a day to be obtained from the Delaware River ; and all future increase in supply is assumed to be taken from this river. We have selected the neighborhood of Torresdale as the site for the new pumping station on the river, because the present site at Lardner's Point will, in our opinion, not be suitable in the future on account of the several large sewers now delivering, or which will soon deliver, a large amount of sewage into the river in that neighborhood.

"From data at hand and from our estimates of the growth of the city, we have made the distribution of the total daily quantity of water required as follows :

"For a supply of 200,000,000 gallons per day :

	Gallons Daily.
Belmont Station	27,000,000
Roxborough Station	15,000,000
Queen Lane Station	58,000,000
Spring Garden Station	50,000,000
Torresdale Station	50,000,000
Making a total of	200,000,000

"It is proposed to add, at Belmont station, one new pumping engine of 20,000,000 gallons daily capacity.

"For a supply of 300,000,000 gallons per day:

	Gallons Daily.
Belmont Station	37,000,000
Roxborough Station	25,000,000
Queen Lane Station	58,000,000
Spring Garden Station	30,000,000
Torresdale Station	150,000,000
Making a total of	300,000,000

"It is proposed to erect, at East Park filter plant, two 12,000,000-gallon pumping engines, to pump from East Park reservoir into the Queen Lane district, in order to supply the deficiency between the amount pumped directly at Queen Lane station and the consumption of Queen Lane district.

"For a supply of 450,000,000 gallons per day:

	Gallons Daily.
Belmont Station	55,000,000
Roxborough Station	37,000,000
Queen Lane Station	58,000,000
Spring Garden Station	—
Torresdale Station	300,000,000
Making a total of	450,000,000

"If the future water supply is obtained from the rivers and filtered, it will be necessary to make a few changes in the pumping machinery and reservoirs.

"At Fairmount, the reservoir is too low for a proper service, being only 94 feet above tide. Also, it is inexpedient to filter the water at this station, and for these reasons we have recommended the abandonment of the Fairmount reservoir.

"The Spring Garden reservoir would be of no use in the new apportionment, and might be abandoned as a reservoir, unless retained for the use of Girard College.

"At Belmont, the present reservoir, with slight alterations, could be used as a settling reservoir. A new 20,000,000-gallon pumping engine should be added to the station at the Schuylkill River, to be used as a reserve.

"By limiting to 150,000,000 gallons per day the amount of water to be obtained from the Schuylkill River, it became necessary to reapportion the amounts to be supplied to each station, as it was evident that at the present time more than the above amount is actually pumped from the Schuylkill River. We found it to be more economical, therefore, to limit the amount of water to be supplied to the Queen Lane district from the Schuylkill River, and to furnish the deficiency hereafter from the Delaware River.

"The quantity thus supplied to the Queen Lane district from the Schuyl-

kill River is to be secured from the East Park reservoir by a new pumping station at the East Park filter plant, with proper engine capacity to pump from this reservoir into the Queen Lane district.

"A portion of the Queen Lane reservoir is to be converted into a clear-water reservoir discharging into the city mains.

"The East Park reservoir, being very large, will not only serve as a storage reservoir for Schuylkill water, but also for the excess delivered in the future from the Delaware River. A part of this reservoir is to be converted into a clear-water reservoir delivering into the city mains

"The new Roxborough reservoir is to be kept in use, but a part of it is to be converted into a clear-water reservoir.

"The Mount Airy reservoir will be used and the old Roxborough reservoir may be temporarily put out of use.

"The Frankford reservoir will be converted into a clear-water reservoir.

"The Lehigh reservoir can be temporarily placed out of use, and eventually converted into a clear-water reservoir if found necessary.

"In assigning the quantity of water to be supplied to the several districts, and the capacity required of the filtration plant for each, consideration has been given to their probable relative growth and increase in population, as some districts, particularly those of suburban character, will undoubtedly show a much greater annual increase than others.

"The lower levels in the Roxborough district, now supplied from the new reservoir, with its great elevation of 41 feet, could be more economically supplied from the Queen Lane reservoir if proper mains were laid for the purpose. Indeed, a portion of the lower Roxborough district is already supplied by a main which taps the Queen Lane pumping main near the station.

"In connection with the gravity supply from the Delaware River, a new distributing reservoir near Olneyville, at the point of discharge of the conduit, is proposed. The cost of this reservoir is estimated at $1,000,000.

"A new reservoir at Belmont, adjoining the present reservoir, for the sedimentation of raw water, may be required when the present consumption has been materially increased. It probably need not be more than half as large as the reservoir recently proposed.

"As the demands of the Belmont, Roxborough and Queen Lane districts increase, the surplus of the Schuylkill water delivered at East Park during minimum flow will gradually diminish; and this deficiency, together with what will be required for increased consumption all over the city, is to be supplied from the Delaware through the Torresdale filter plant. When the Schuylkill is flowing above its minimum, which will be during most of the year, the supply will be ample to keep the East Park plant in full service as well as the others.

"To abandon completely at this time the present Schuylkill plants would mean the abandonment of much valuable pumping machinery and other works, and also a loss of time in making the change. This change would require not only that a large additional plant be in operation on the Delaware before the Schuylkill plant could be removed, but also the laying of large and costly mains to bring the water to the city.

"Upon the completion of the proposed Torresdale pumping station the Frankford station would be abandoned.

"The standpipes at Belmont, Roxborough and Chestnut Hill will be kept in use, but will be supplied with filtered water instead of with raw water."

On the subject of water meters the experts say:

"No restriction should be placed upon the use of water required for health, comfort and cleanliness, nor should a part of the community be encouraged to deprive another part of its full quota of water. We are, therefore, emphatically of the opinion and strongly urge that all practicable means should be adopted to secure a fair and equitable distribution of the city's water.

"We know of no better means to this desirable end than the introduction of water meters, not only for all business properties and manufacturing establishments, but also for such private consumers as are found by the Department of Public Works to be carelessly wasting water from the public supply. This remedy is available and simple, and it has been already adopted in many cities with entire satisfaction.

"We earnestly recommend the introduction of meters for the city of Philadelphia with perfect confidence that the private consumer is given full and ample use and enjoyment of all water for his needs and comforts at no greater cost, and probably in many cases even less cost than the present rates impose. The meter is uot proposed to increase the revenue, but to prevent one citizen from depriving another one of his rightful share of water. A private corporation would introduce meters at an early day if not restricted by law, and would at the same time encourage consumption in every way.

"The lack of a sufficient supply of water in various parts of the city is due either to a deficiency of distributing pipes, to the lack of pressure from the reservoir, to the want of pumping machinery, to a waste of water which reduces the head, or to two or more of these causes combined. The remedies are apparent."

NOTES AND COMMENTS.

SURVIVAL OF AN ANCIENT INDUSTRY.

Among the many industries connected with the iron and steel trades, there is one survival from former times in England, which is of great interest. This is the mail chain armor manufacture in Walsall. J. W. Hawkins & Co., Limited, who contract with the Government for the supply of spurs, bits, stirrups, harness, buckles, chains, etc., also supply mail chain jackets and other steel productions for use in India, Central and South America and other countries. These jackets of mail, which weigh from 15 to 18 pounds, are worn by army officers, and sometimes by Indian native princes, and are made of steel rings of ⅜ inch diameter. It takes about 3,cco rings to make a square foot of armor. These rings are formed out of soft steel wire of 14, 15, 16 or 17 B. W. G., which is revolved around mandrels 4 inches long, and of the same diameter as the rings required, each mandrel taking about 6 feet of wire, and subsequently divided by a hand saw. Hardening is accomplished by putting them upon trays and plunging them when red hot into oil, after which they are polished in revolving drums.

DISCOVERY OF A NEW PLANET.

Herr Witt, of the Berlin *Urania*, has announced the discovery of a new member of the solar system, which is now affirmed to be a new planet revolving round the sun in a strongly elliptical orbit, between the Earth and Mars, in a period of 645 days.

It is assumed that the new body entered the planetary system recently as the "result of some disturbing influence on the part of one of the large planets." The presence of the newly-described planet has been confirmed by Charlois, at Nice, who has taken photographs of it simultaneously with Witt at Berlin.

PHOTOGRAPHING PROJECTILES IN FLIGHT.

In discussing some curious phenomena observed in studying the flight of projectiles, the *Engineering Magazine* mentions the interesting fact, in connection with the successful taking of projectiles in flight, that, "since no shutter could be made to act quickly enough to make the brief exposure necessary for these photographs, and as correct timing would be impossible, the bullet itself is caused to make the exposure by making an electrical contact between two wires, just as it passes the center of the photographic field, thus closing the circuit of a Leyden jar, and producing a bright spark, which furnishes the illumination for the photograph. The bullet is thus reproduced in silhouette."

SILICATE OF SODA (WATER-GLASS) IN REFINING PETROLEUM.

Drugs, Oils and Paints recommends highly the use of silicate of soda for the refining of the heavy (spindle to cylinder oils) petroleums. The silicate is used as a neutralizing agent after the treatment with sulphuric acid, and is said to be highly efficacious. It may be used either alone or in connection with caustic soda.

Its advantages are said to be :

(1) A smaller percentage of sulphuric acid may be used for heavy oils ; although dark oils are thereby obtained, the decolorizing property of the separated silicic acid soon changes them into pale oils, which are readily salable.

(2) The emulsion deposits quickly, through the agency of the separated silicic acid, which acts upon the suspended impurities as a precipitating agent.

SOLID PETROLEUM.

Attempts have been made from time to time to solidify petroleum refuse for use as a fuel. The latest effort in this direction, says *Industries and Iron*, is that of Herr Kohlendorfer, a Bavarian. In his process about 10 per cent. of soda lye, with 10 per cent. of fatty matter, is treated in a boiler, and enough petroleum refuse is added to the heated mass to make up 100 parts. This mixture is then heated, under constant stirring, for about an hour. The temperature is prevented from reaching the boiling-point of petroleum. In this incipient state of saponification the mass acquires the property of taking up large quantities of fluid rock oil. The mixture is run into moulds and allowed to cool, when it may be cut into pieces of any desired form.

Franklin Institute.

[*Proceedings of the stated meeting held Wednesday, October 18, 1899.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, October 18, 1899.

MR. JAMES CHRISTIE in the chair.

Present, 78 members and visitors.

Additions to membership since last report, 23.

The following gentlemen were, on the recommendation of the Board of Managers, elected as honorary members, viz.:

Prof. Harvey W. Wiley, Washington, D. C.
Dr. Chas. F. Himes, Carlisle, Pa.
Dr. Edwin J. Houston, Philadelphia.
Mr. Ralph W. Pope, New York.
Mr. Chas. Kirchhoff, New York.
Mr. John Fritz, Bethlehem, Pa.
Dr. Coleman Sellers, Philadelphia.
Dr. T. C. Mendenhall, Worcester, Mass.
Rear-Admiral Geo. W. Melville, U. S. N.
Dr. Rob't H. Thurston, Ithaca, N. Y.
Hon. Frederick Fraley, Philadelphia.
Prof Martin H. Boyé, Coopersburg, Pa.
Hon. Abram Hewitt, New York.

The following were elected as corresponding members, viz.:

Mr. T. Commerford Martin, New York.
Mr. Wm. F. Durfee, West New Brighton, N. Y.

Amendments to the by-laws were approved, reducing the distance-limit for non-resident members to twenty-five miles from Philadelphia; also, permitting non-resident members to make a life-membership payment of forty (40) dollars, in lieu of annual fees.

Mr. B. S. Lyman, Chairman of the Committee on Library, represented the need of facilities for the proper storage of the large pamphlet collection of the library, to make the same safe and accessible.

The Secretary called attention to the newly-established School of Naval Architecture, and to the annual announcement and program of lectures just issued.

The papers of the evening were read by Mr. Strickland L. Kneass, on "Giffard's Invention and the Development of the Self-acting Injector," illustrated by models and diagrams; and by Mr. Wm. B. Wait, Superintendent of the New York Institution for the Blind, on "An Apparatus for Embossed Printing for the Use of the Blind," illustrated by specimen machines.

The subjects of both papers were referred to the Committee on Science and the Arts for examination and report.

The Chairman expressed the thanks of the meeting to the speakers of the evening.

Adjourned. WM. H. WAHL, *Secretary.*

JOURNAL

OF THE

FRANKLIN INSTITUTE

OF THE STATE OF PENNSYLVANIA,

FOR THE PROMOTION OF THE MECHANIC ARTS.

VOL. CXLVIII, No. 6. 74TH YEAR. DECEMBER, 1899

CHEMICAL SECTION.

PHOTOGRAPHIC AND MICROSCOPIC BRANCH.

THE MAKING OF PHOTOGRAPHY.

BY CHARLES F. HIMES, PH.D., LL.D.

[An Address delivered in Convention Hall, National Export Exposition, Monday, October 2d, on the Occasion of the Celebration of the Seventy-fifth Anniversary of the Franklin Institute.]

Standing at the close of three-quarters of a century, marked by intense scientific activity attended by amazing progress along all lines, the most superficial consideration of photography and its applications exhibits it as one of the most important factors in the life of to-day, evolved from that activity. Using the term in its most comprehensive conventional sense, it touches at numberless points all sciences, all professions, all trades and industries. It would be a hopeless task to compress into the limited time, very properly assigned to this the most recent branch of this

Section, on this occasion the most imperfect statement of the achievements of photography, to say nothing of indulgence in speculations as to its further possibilities. But the occasion does not seem to require it. It belongs to the Franklin Institute, and at this, its seventy-fifth anniversary, it seems appropriate to consider photography and its history in its relations to the Institute, for photography and the Franklin Institute were young together. They have grown up together. It has had a share in the making of modern photography. When the Franklin Institute was founded, the word photography had not been coined, or at least had not struck the ear of the lexicographer. It may have been one of many words used according to the fancy of the individual investigator to connect the accumulating facts of an inchoate branch of science; but it was not the first, and when it did put in an appearance, it was not free from adverse criticism. There was a time when heliography may have been preferable, but with the extended industrial use of the electric light, magnesium light and even gas light, to say nothing of the Röntgen rays, it would be much more of a misnomer to-day than photography, which word must be regarded as holding its place to-day, as the survival of the fittest. It is an interesting coincidence, too, that the year that witnessed the founding of the Franklin Institute is, perhaps, the most important in the history of photography. It was not, it is true, the year in which any important discovery was made or announced. It was simply the initial year of those experiments that culminated in the discovery that constitutes the birth of modern photography. It was in that year that Daguerre first turned his attention to photographic investigations. For after all has been allowed that is to be credited to, or even claimed for others, he still remains the central figure in photographic history. Photographic events date backward and forward from him. Without his discovery all photographic that preceded him would have been embalmed in the history of science, overlooked and perhaps entirely lost, until revived by the touch of some such great discovery as his. His success at once caused all records to be ransacked, to be assured that he had, indeed, made so unique and mar-

vellous a discovery. As usual in such cases, some things were found that at first sight seemed to reduce his claims, but which, when fully considered, do not affect them in the least. In 1824, then, he entered upon the fourteen years of solitary, discouraging, almost hopeless, but unintermitted experiments, that finally resulted in the discovery to which his name has adhered. Accustomed as we have become to the almost daily announcement of similar great unexpected and unheralded discoveries, we can hardly realize the sensation it created, nor the struggle between the great desire to believe it true, and the incredulity of that day, so much greater than that of our own. This was even heightened about that time by the then recent "Moon hoax," to which the announcement of Daguerre's discovery was compared, even by scientific men. In his classical history of chemistry, Kopp, who doubtless wrote from personal acquaintance with individuals present in Paris at the time, in seeking for a parallel to the excitement occasioned by Davy's great discovery of the metals of the alkalies, in the early part of the century, says of it, "something like that occasioned by Daguerre's discovery in our time." From that date, 1839, we pass rapidly backward into the hazy prehistoric period, that belongs to every branch of science, from which many interesting items have been recovered by the curiosity aroused by the practical success of his process. From that date forward, we have only to note an immediate, rapid, steady development. There is no disposition by this statement to unduly magnify the merits of Daguerre, much less to minify the claims of others, but simply to accentuate the epoch-making character of his discovery. So much has been written with a bias, in many cases inspired by national partiality, and is being so frequently repeated, that the salient and indisputable facts are often overlooked. It may not, therefore, be out of place here to bring together rapidly facts generally received, in such connection and sequence as to exhibit the origin and making of modern photography.

What then was the condition of photographic research in 1824? Overlooking all alchemistic and other accounts, however curious and interesting, but without effect upon

the history of photography, we find, in 1777, the illustrious Swedish chemist, Scheele, engaged in investigating scientifically, carefully, we might almost say exhaustively, the interesting fact, long known, that silver chloride darkens under the influence of light. He allowed sunlight that had passed through a prism to fall upon silver chloride spread upon paper on the floor of the darkened room, and demonstrated that the violet ray was most effective in producing the change. He further established the fact that chlorine was liberated in the operation. But this, the usual, statement of these facts, and a correct one from the point of view of to-day, conveys a very wrong impression of Scheele's purpose, and of his interpretation of his results. The object of his investigation was not the action of light on silver chloride, but the action of silver chloride, or horn silver, as it was then called, on light; and he did not state his results in the way given. The scientific world of that day was dominated by the curious, almost fanciful, phlogiston theory of combustion. That hypothetical something, or nothing, was always present in their thoughts whilst investigating. Scheele was trying to demonstrate that phlogiston was present in sunlight, and he explained his results by saying that silver calx removed the phlogiston most rapidly from the violet ray. The change in the silver chloride he explained as loss of dephlogisticated spirit of salt. Disentangled then from the theories of his day, Scheele made two important discoveries, which we recognize to-day as photographic. Many eminent investigators repeated his experiments. In 1798 Rumford, as the result of elaborate experiments, contended that the change was due to heat, and not to light. In 1801 Ritter, incited doubtless by the detection of heating effect, by Sir W. Herschel, the year before, in the space beyond the red of the spectrum, announced the discovery of photographic effect in the invisible region beyond the violet. He also demonstrated an opposition of effect of the red and violet rays, and explained it by an oxidizing action of the former, and a reducing action of the latter. In 1802 Wollaston arrived at substantially the same results; but in investigating Ritter's explanation of the opposition of the red and violet rays, from which he dis-

sented, he employed a photographic substance of a new class, namely, gum guaiacum, and considered its change of color under the influence of light. In 1804 Young employed a silver salt successfully to investigate Newton's rings, projected by a solar microscope. So Vogel, Seebeck, Senebier, Davy, Berard, in fact almost every scientific man of prominence of that period, pursued similar lines of investigation. The motive of most of these was strictly scientific, such as the determination whether the solar beam contained three essentially different agents, of which the actinic was but one, the photogenic production of the colors of the spectrum, the exploration of the invisible regions of the spectrum, and the like. In the apparent chaos of carefully observed facts, there are many that advanced photography of to-day imparts new interest to, and that might well repay reinvestigation. There was but one notable attempt at practical application of facts. In 1802 Thomas Wedgewood, son of the porcelain manufacturer, in connection with Davy, published a method of copying pictures painted on glass, fibers of leaves, wings of insects, and so forth, by pressing them in contact with paper coated with nitrate or chloride of silver and exposing to sunlight; but, failing in all their efforts to prevent the continued darkening of the pictures obtained in this way by the action of light, they were obliged to preserve them in the dark, and could only examine them by candlelight.

During the decade preceding the founding of the Institute there was almost a complete lull in scientific activity along these lines. During this time, however, there was one man, Nicephore Niépce, who had been working on from 1814, with great tenacity of purpose, trying to fix the images of the camera. He had sufficient suggestions of success to keep him at work. He did not approach the subject from the scientific side, nor from purely scientific impulses, but with a desire for immediate practical results. He had become interested in the recently-discovered process of lithography. The difficulty of procuring suitable stone suggested the use of metallic plates, and it occurred to him to substitute light for the hand in drawing the pictures. After experimenting with various substances, among them

silver chloride, he discovered that bitumen of Judea was rendered insoluble in certain solvents by the action of light. He coated metallic plates with a thin varnish of it; exposed them when dry to the sunlight under engravings, previously varnished to render them more transparent, and then dissolved out the unchanged bitumen of the parts protected from the light. After a measure of success in thus copying engravings, he experimented with the pictures of the camera on similar plates, and there seems to be no question that about 1827 he had obtained pictures by this process, however imperfect. He named the process "Heliography."

In 1824, Daguerre, entirely ignorant of Niépce or his work, entered upon a similar pursuit, upon parallel lines, inspired by a similar desire for immediate practical results. He was a scene painter in Paris, and an artist of no mean character, and of great popularity in that city. The diorama, invented by him, was the sensation of the day. Crowds were entertained by its surprising effects. He was aided by the camera in preparing his scenes. The wish to fix its fleeting pictures might occur to any one, but it took complete possession of him, although the pursuit was more unpromising than that of the alchemists. He worked alone and in secrecy, with but little encouragement. His methods were empirical rather than scientific. About 1826 he learned of another worker in the same field. He immediately wrote to him. Niépce, distrustful of the unknown writer, threw the letter in the fire. A letter a year later met with a better reception. The correspondence continued, at first with almost suspicious reserve. Niépce visited Paris, met Daguerre, was greatly impressed with his diorama. Both seemed to enjoy an exchange of experiences that belonged to them alone. Niépce wrote his son, that Daguerre persisted in regarding his (Niépce's) process as better than his own, but that one thing was certain, they were entirely different. A partnership, styled Niépce-Daguerre, was formed, with equal interest. The article of agreement, dated December 14, 1829, was signed by Niépce as "Land owner at Chalons sur-Saone," and by Daguerre as "Artist Painter, Member of the Legion of Honor, Manager

of the Diorama." Under the terms of the partnership, Niépce contributed his process of Heliographie, and his experiments, which Daguerre agreed to assist in improving, and also contributed his improved camera, which was regarded as of great value, as it most likely was. Daguerre improved the process, but was diverted altogether from it by the accidental discovery of the sensitiveness of silver iodide to light. In the bitumen pictures the blacks of the original were represented by bright polished metal, from which the unchanged bitumen had been removed, and the whites by the changed bitumen. To convert these negative pictures into positives, Niépce experimented with a variety of substances, among them vapor of iodine, to darken the exposed metal, and then dissolved off the bitumen from the whole plate. It is said that Daguerre observed, that the shadow of a spoon that happened to be lying on a polished silver plate that had been exposed to the vapor of iodine, was permanently impressed upon it. Slight as every one knows this direct effect of light on iodide of silver to be, Daguerre seemed to see in it new possibilities for camera pictures. Niépce, however, after experimenting with it at Daguerre's suggestion, expressed regret that he had lost so much time in following his recommendation. He repeated that he did not see that they could hope to secure any advantage from this process, and suggested other substances as better. Niépce died in 1833. Success seemed as remote as at the formation of the partnership. The partnership was renewed with the son, Isidore Niépce. Daguerre now entered with even greater enthusiasm and undivided effort into the pursuit. He neglected the diorama, and lived in his laboratory, to which no one had access, not even Isidore Niépce. He became so much wrought up by his unsuccessful experiments that his wife, according to Dumas, consulted physicians in regard to his sanity. Finally there came to his assistance an accident which conducted to a fundamental discovery, as fundamental to-day as it was then. The mode of the discovery has not only a species of romantic interest of its own, but, as I recollect it, given by Professor Liebig in one of his lectures, as one of the finest specimens of the

inductive method, coming thus from one thoroughly familiar with the Paris of that day, it has an added air of authenticity that may excuse the narration of it in this connection. Daguerre's method of experimenting was to expose polished silver plates to the vapor of iodine until coated with a layer of iodide, then to subject them to the image in the camera. These plates, always without the hoped-for result, or at most the very feeble direct effect, were repolished, reiodized, re-exposed in the camera with the same disheartening results. On one occasion, upon removal of such an exposed plate from a closet, in which it had been stowed, to repolish it for a new experiment, to his great surprise he found upon it the view to which it had been exposed in the camera, not an uncertain, feeble picture, such as he had been accustomed to, but a strong, clear, unmistakable one. He exposed another plate in the camera, without visible effect, stowed it in the closet, again to find the invisible picture put in an appearance. He had no way of explaining the result. All his years of investigation furnished him no clue to the influence at work. He set about systematically to discover it. He could only conclude that it must be something in the closet. He placed plate after plate, after exposure in the camera, in the closet, each time first removing something from the closet. Each time the invisible became visible. At last nothing remained but some mercury spilled on the floor of the closet. Thus by this method of elimination the magician was detected. It was a short step to subject plates that had been exposed in the camera to vapor of mercury, and the daguerreotype process was complete. But the discovery was far more than simply that of a process. It was that light can produce an invisible effect, a latent effect, as it has been called, previously entirely unsuspected, which may be rendered visible by suitable agents, which we call developers, and, what was of most practical value, an effect produced in so short a time as to render camera pictures easily possible. Upon it all modern photography, the prime factor in which is the negative, is based, and a great part of the photographic literature of to-day deals with development and developers. If one name, then, is to be selected

as representative in the history of photography, there can be no question but that it should be that of Daguerre. This seems to have been the view taken by the authorities of the Congressional Library at Washington, and there was a singular fitness in placing his name there with that of Guttenberg in the Hall of Inventors. The name of Niépce might have been placed there too, but certainly in a subordinate position, or have been left out, as it has been, without manifest injustice, although his merit is of a high order. He was an independent, ingenious, indefatigable experimenter and investigator. His bitumen process may be regarded as entirely his own, although the important principle underlying it, of change of solubility effected by light, to-day of widely-extended application, was, at least, suggested to him, according to a letter by him, by the experiments of Wollaston with gum guaiacum, which experiments, however, his own failed to substantiate. Although his process was measurably successful, it was extremely slow as a camera process, requiring from six to eight hours in the sunlight, and not only imperfect, but impracticable, and, looked at even from our present point of view, had in it no possibility of growth or development into a practicable camera process. There is nothing in it in common with, or suggesting in any degree, the negative processes of to-day, and, however creditable his work and its results, photography, as we understand it, would have begun and ended with Niépce and his process. The discovery of Daguerre, however, of a latent effect of light, produced in a much shorter time than any direct effect and developable, was a unique fact in science. It was independent of, and unsuggested by, anything that had preceded it. The guesses of Sir John Herschel in regard to it, after its announcement and before its publication, accentuate this important fact. It was in the line of his investigations, and in commenting on Daguerre's concealed process, as he termed it, he gave four possible explanations of it, no one of which proved to have anything in the remotest degree in common with it, as published a few months later. It had in it all the possibilities of the negative processes of to-day, in which time of

exposure has been reduced to the smallest fraction of a second, as shown in the kinetoscope and the snap shots of the amateur. The development of modern photography, with all its practical applications, from it was like the growth, and very rapid growth, from a germ.

Had this fact been left by Daguerre with simply the suggestion of a practical application, its importance would have been the same. But he gave a process founded upon it commercially complete, immediately available, with results possessed of highest intrinsic merit, which contributed much to the growth of practical photography. An account from a Parisian newspaper of the day will serve to emphasize this statement as to the character of the results: "The deputies" (of the French Assembly) "during the day crowded to the room attached to the Chamber of Deputies, in which the pictures were displayed." "They were struck with the marvellous minuteness of detail which these views, especially those of the streets, exhibited." "In the one of the Pont Marie all the minutest indentations and divisions of the ground, or the buildings, the goods lying on the wharf, even the small stones under the water at the edge of the stream, and the different degrees of transparency given to the water, were all shown with the most incredible accuracy. The use of a magnifying glass revealed an infinity of other details quite undistinguishable by the naked eye, etc." This might be taken as the description of a first-class photograph of to-day. But it may be said, after all, it was only the result of a happy accident. That could be said of many discoveries. The list of such accidents to purely scientific men would be a long one. But such accidents only happen to such men as work their way across their paths, and can appreciate them, otherwise they come and go unnoticed. The accident is frequently the final event of a long series that seems to be credited with too large a share of the ultimate success. Daguerre was a lucky fellow, but he was not a scientific Micawber. The commercial reception of the discovery is interesting, perhaps instructive. In 1838 the process was considered so far advanced as to be put in operation. From March 15th to April 15th subscription books

were kept open for 400 shares of 1,000 francs each. Not a share was taken. The process was offered for 200,000 francs and no purchaser appeared. In January, 1839, the secret was imparted to Arago, who was so impressed by it that he exerted himself to procure recognition for it from the French Government, which pensioned Daguerre and Niépce, and gave the discovery as a gift to the world, without the restriction of a patent, except in England, where one had already been taken out. On the 10th of August, 1839, the process was communicated by Arago to a joint meeting of the Academy of Sciences and the Academy of the Fine Arts, held for the purpose. The Mazarin Palace in which the meeting was held was not only filled with an audience of unusual character, but the approaches to it were crowded.

This early period of photography cannot be passed over without mention of the name of Henry Fox Talbot, of England. He was a man of many-sided scientific character, and an independent investigator in the photographic field prior to Daguerre's discovery, and therefore not inspired by it to investigation. In 1839, January 31st, he read a paper before the Royal Society, entitled, "Some Account of the Art of Photogenic Drawing, etc.," embodying a practical process on paper based on the abandoned process of Wedgewood and Davy, which he improved and also completed by fixing the pictures, although imperfectly, in a solution of common salt or potassium iodide. The substitution of sodium hyposulphite, first suggested by Sir John Herschel, for the iodide soon followed. He further suggested indefinite photographic multiplication of the paper originals, by taking impressions from them on similarly prepared paper, and upon the publication of Daguerre's discovery of a latent effect of light, was quick to apply it to the preparation of a paper sensitive enough for camera impressions; and by rendering these transparent, greatly facilitated indefinite photographic multiplication of the original negatives as positive pictures, although the terms negative and positive, in this connection, were first used by Herschel. His Calotype process was patented by him in 1841. Although there is nothing in it that would call for

the association of his name with those of Daguerre and Niépce, yet, as an independent investigator, scientifically trained, he deserves prominent mention, as one whose applications of known facts at once greatly stimulated the practice of photography and its consequent rapid improvement. In addition to the introduction of photographic multiplication by the use of a translucent support for the sensitive compound of silver, the replacement by him of the formation of such a compound by the direct combination of the halogen with the silver, as in Daguerre's process, by the reaction between silver nitrate and a metallic haloid, was typical of more modern photography.

It is interesting at this point to note the reception of the discovery in America. There was at least one man thoroughly ready to appreciate the scientific features of the process and to apply it. The numerous papers contributed to the *Journal of the Franklin Institute* by Dr. John W. Draper, several years before Daguerre's discovery, detailing investigations, are classical, and surprise us even to-day by their minute accuracy and anticipation of solutions of questions long subsequent. But he escaped making Daguerre's discovery. He succeeded, however, in doing what Daguerre had not yet succeeded in accomplishing. He took the first portrait by Daguerre's process, although, as we shall note, this claim is disputed in favor of a Philadelphian. He took the first photograph of the moon. He applied the process in a variety of ways in scientific investigation. But nowhere did the announcement lead to practical application as quickly as in Philadelphia. The old American Philosophical Society and the then young Franklin Institute had members alert for anything that was new in science. Joseph Sexton took the first photographic view in America, out of a window of the Mint, with very crude apparatus in October, 1839. Robert Cornelius, a lamp-maker, took a portrait in the latter part of 1839, some claim before that made by Draper. The Franklin Institute, in its exhibition in 1840, displayed some of the first results. The *Ledger*, in its account October 12th, states: "Throughout the room are various specimens of

the daguerreotype. They consist mostly of miniatures." This shows great enterprise for a day of sailing vessels, when it is remembered that Daguerre's process had only been made public in Paris in August, 1839. But the part that Philadelphia had has been so fully treated in a lecture before the Franklin Institute several years ago by Mr. Julius F. Sachse* and published in its *Journal*, that I can do no better than to refer to it. But one fact of permanent effect, and of exceeding interest in this connection, is the strong body of amateurs in the art which sprang up in Philadelphia, and which has always characterized it; strong not only in numbers, but in scientific character and motive.

I think I am not mistaken when I assert that the first independent photographic society in America was the Philadelphia Photographic Society, as the American Philosophical Society was the earliest scientific society. It was organized in the heroic days of photography, when the practice of photography meant a great deal; when press-the-button and snap-shot work were unknown. Members of the Philosophical Society and of the Institute were active in founding it and making its creditable records. Dr. Coleman Sellers, President of the Institute, was a prolific writer on photographic subjects, always instructive and practical. Joseph M. Wilson, who is doing so much to give Philadelphia pure water, also a former president, has been an enthusiastic amateur from his boyhood. There are so many others, who have not filled that high position, active in advancing photography, that I must refrain from mentioning any, except Mathew Carey Lea, so well known as one of the most indefatigable, painstaking scientific investigators, whose contributions to this subject, largely along lines all his own, are not only of present practical value, but full of promise to investigators, which the future will doubtless realize. His apparatus bequeathed to the Franklin Institute will form a fine nucleus for the encouragement of photographic investigation. When Professor

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* Sachse, Philadelphia's Share in the Development of Photography, *Jour. Frank. Inst.*, **135**, 271.

Henry Morton, then Secretary of the Institute, organized the highly successful expedition to photograph the total eclipse of 1869, under the auspices of the National Government, he was able to draw largely from the membership of the Institute for his efficient corps of observers.

But to return to the development of photography. One of the most tantalizing defects of the process, as published by Daguerre, was its slowness. It suggested portraiture, but just came short of desired success. In 1840 the requisite increase of sensitiveness was obtained by the use of bromine in connection with iodine, and the trio of silver haloids in use today was completed. This use of bromine as an accelerator, as it was called, was published by Goddard, of London, in 1840. The honor of its introduction is also claimed for Philadelphia, where Dr. Paul Beck Goddard, a singular coincidence of names, employed it as early as 1839, but, as he kept the fact a secret until 1842, whilst we are privileged to believe that he first used it, we cannot claim the honor for him as against prior publication. The process, it seems, was employed at once commercially here with greater success than in France. Daguerreotype portraits were taken at five dollars each. The Calotype negatives of Talbot, with the objectionable grain of the paper, suggested better things. Glass had been used by Herschel in some experiments with silver chloride, and negatives on glass, with albumen as the vehicle of the silver iodide, which afforded excellent paper prints, were first produced by Niépce de St. Victor, nephew of Niépce, in 1847. The daguerreotype began to recede in importance, and amateur practice of photography was stimulated. In 1850 the greatest advance since the time of Daguerre was made by the introduction of collodion, a solution of guncotton, then recently discovered, as a vehicle of the sensitive silver iodide. Glass and collodion seemed to possess all desired properties for photographic purposes. Nothing better seemed possible. The daguerreotype disappeared entirely. A collodion positive process on blackened metal, an American invention, in a measure took its place, and survives to this day as the tintype. The collodion process, however, was soon found uncomfortably cumber-

some by the growing number of amateurs, requiring as it did the completion of the whole process whilst the plate was still wet, necessitating the impedimenta of tents, bulky solutions, fragile vessels, etc., for outdoor work. The dispute continued for a decade between *humidus* and *siccus* as to the relative merits of the wet process and various dry-plate processes devised from time to time. At last, in 1862, the tannin dry-plate process of Major Russel seemed to be satisfactory in results, but slow in exposure and time-consuming in the preparation of the plates. In the wet-collodion process the metallic haloid was added to the collodion and the plate coated with it immersed in a solution of silver nitrate, where the reaction took place producing the silver haloid. The question naturally arose, why not eliminate one of the most troublesome factors of the process by adding the silver salt to the collodion? In 1865 Bolton & Sayce overcame the intrinsic difficulties, and produced an emulsion of silver haloids with collodion suitable for the purpose. The process became commercially available, and bid fair to revolutionize photographic practice. But in 1871 Dr. R. L. Maddox succeeded in producing workable plates with an emulsion of gelatine and silver bromide. The process was at once taken up, and brought by rapid stages by different workers to a high degree of perfection. Dry plates of wonderful rapidity, of great certainty and ease of manipulation and of practically indefinite keeping qualities were soon placed upon the market. Again a Philadelphian, and member of the Institute, John Carbutt, manufacturer, was among the very first to recognize the commercial possibilities of the new process and erect a plant to meet the demand sure to spring up. The professional adopted them slowly. The amateur recognized in them the long-desired dry plate. Photographic societies in the United States, mainly of amateurs, increased in the decade from 1883 to 1893 from 9 to 120, or more than twelvefold. Manufacture of cheap, but good, dry-plate outfits, which dispensed with the more expensive wet-plate holder, assumed very important proportions. Dry plates and improved developers and appliances for dry plates began to

predominate in the advertising columns of the journals, and detective cameras, as hand-cameras were generally called at first, were largely advertised in periodicals in which photographic advertisements had not appeared before. But the amateur complained now of the weight of glass to be carried. A return to paper for negative purposes was made, expensive apparatus devised to coat it and with excellent results. The critical amateur withheld his patronage. At last a substratum was produced in celluloid, singular to say with guncotton as a chief ingredient, having the essential photographic properties of glass, but tough as well as light. But still the enthusiastic, patient amateur, with almost infinite capacity for trouble, but always seeking lines of least resistance, striving to avoid the unnecessary in his work, and keenly sensitive to discomfort, complained that he had to retire to the dark-room or changing bag before his day's work was half done. Again his complaint was met by the daylight loading roll of sensitive film, which will permit a year's snap-shotting without entering the dark-room.

The discovery by Professor Vogel, in 1874, of the possibility of rendering plates sensitive to colors generally regarded as non-actinic, by treating them with suitable dyes, constituted the most distinct advance in photography since the days of Daguerre, widening its range of applications. Fred'k E. Ives, of the Institute, published the first perfected orthochromatic process. Orthochromatic plates soon appeared in the lists of up-to-date manufacturers.

The processes for multiplication by action of light have sympathized with the general progress of the negative practice, but have not kept pace with it. The direct printing out processes in use from the earliest albumen coated silver chloride paper down through the papers of various names, coated with gelatine or collodion as vehicles, with their dependence on daylight for printing and their subsequent operations, are ante-Daguerrean in principle, and almost anachronisms in this day. The developing papers, with their independence of daylight, and in the Velox-type permitting developing by comfortable gaslight, and, with suitable apparatus for exposure, yielding 5,000 prints per day, seem more nearly up to date.

But all processes with silver are viewed with distrust in regard to permanency. Two processes at least are regarded with more favor in this respect, and are recommended by the National Photographic Records Association of Great Britain for its photographs. The carbon or pigment process, which carries back in principle to the time of Niépce, based upon the discovery of Mungo Ponton in 1839, of the loss on exposure to light of solubility or stickiness by gelatine and other organic substances, mixed with alkaline bichromates. The other, the platinum process dependent upon the reduction of a ferric to a ferrous salt by light, one of the many discoveries of Sir John Herschel, and the reducing action of the latter on a platinum salt also present in the paper. The process, originally patented by Mr. Willis, now free, is simple in manipulation, and yields artistic effects as well as permanent prints. The blue print process, humblest of all, but yielding a larger acreage than all others, also originating with Sir John Herschel, is based on the reduction of a ferric salt, and as practised to-day, also in some degree upon the reduction of a ferricyanide.

But a thought ever present with investigators has been the multiplication of pictures by other than purely photographic methods. Niépce started with the motive of etching plates by means of light for printing. Attempts were early made to convert the daguerreotype into a printing surface. In recent years processes based on the properties of gelatine mixed with alkaline dichromates have been commercially highly successful, as photo-lithography, the heliotype, Woodburytype, swelled gelatine and washout gelatine processes, etc., some capable of rendering all the tones, others restricted to black and white, but none of them meeting the growing demand for typographic blocks capable of rendering the shades of the original. At an early day it was found that by breaking up the shades by a grain imparted to the printing surface in different ways, half-tones could be simulated, and the line screen was one of the methods for so doing. But in none of these methods was there an attempt at what might be termed a discriminating grain, a precise rendering

of the shades, as an engraver would do, by lines and dots of varying sizes and separation. In 1891, Frederick E. Ives, of our Institute, patented and conducted commercially a process that might be characterized as ideal in this respect. By it all the tones of photographs and wash drawings could be faithfully rendered by typographic blocks. The testimony most conclusive on this point, perhaps, is the criticism of the art critic of one of the leading dailies of New York, of engravings in a work which called for art of high character. To quote his words in regard to some pictures selected by him as the "finest in the book," he says: "Without detracting from the artist's meed of praise, it may be added that the most remarkable thing about these illustrations is the extraordinary skill displayed by the engravers," and he speaks of the "marvellous delicacy of precision and touch," "power of taking up the theme submitted by the artist," etc., and yet they were soulless photo-engravings by Mr. Ives' purely mechanical process. The blunder of the critic does not reflect on his professional character, but only on his ignorance of the resources of photography. This process has been largely replaced in recent years, for the requirements of the general trade, by the more facile line screen half-tone process, greatly improved by the variation and proper manipulation of the screen and stops employed, and by attention to the optical conditions involved.

Color photography, the dream of every one interested in photography, has seemed to many beset with apparently incompatible conditions, and the unattainable limit of photographic progress. It has none the less, from the earliest period, engaged the attention of the ablest investigators.

A measure of success has been announced from time to time, by Seebeck in 1810, and subsequently by Sir John Herschel, Becquerel, Niépce de St. Victor, Poitevin, Simpson and others. In all cases a difficulty in fixing the pictures has prevented a much-desired general inspection. The following extract from a letter of Sir John Herschel, in 1865, is one of the most favorable accounts: "I received a complete colored spectrum picture from Becquerel several years ago, which is still as fresh in color as when received. The

whole spectrum from end to end, if not brilliant, is still distinct. I seldom examine it, and only by lamplight." The more recent process of Lippmann, founded on interference of light, is of great scientific interest, but, if it has a commercial future, has not yet passed its experimental stage. Other less direct processes seem more practicable. The so-called Jolly or McDonough process, dependent upon a taking screen of lines in intimate contact, colored in series red, green and blue, placed before the plate in taking the negative and used in viewing the result, is also short of commercial success. The heliochromic process of Frederick E. Ives, in conjunction with the Kromskop, comes nearer the complete realization of reproduction of natural colors, and is commercially available. It requires three negatives simultaneously taken, representative of the Young-Helmholtz-Maxwell color sensations, and three positives simultaneously presented to the eyes in the Kromskop, by light through glass or screens (red, green and blue-violet) suitably colored for each. The camera for taking the negatives and the instrument for viewing the positives are ingenious and practicable. Until some process based upon some new material, or new principle, is discovered, this process is likely to hold its present place. Possibly the silver photohaloids investigated by M. Carey Lea may yet lead to the perfect-color process.

The scientific world, hardly recovered from the shock of surprise at Röntgen's discovery, and undecided whether it is dealing with rays or emanations, led by it, seems entering a new and broader field of investigation, almost uncanny in some of its aspects. The terms Becquerel rays, Russel rays, metallic radiations, vaporography and the like are full of import. As stated by Dr. Crookes, "Some bodies without special stimulation are capable of giving out rays closely allied, if not identical with those of Röntgen, and it would almost seem, from the important researches of Dr. Russel, that this ray-emitting power may be a general property of matter, for he has shown that nearly every substance is capable of affecting the photographic plate, if exposed in darkness for a sufficient time." The list of active substances is a long

one, to which a recent investigator has added the human body. The rays pass through many opaque substances, and are checked by others. They excite fluorescence. Already they have led to the discovery of a new metal by Madame Curie, and named polonium, possessing 400 times the energy of uranium, which has hitherto held the highest place. It was announced in the morning paper that Prof. Geo. F. Barker has brought with him from Paris, a specimen of the new metal, and we trust we may look for some demonstration of its properties at an early day. This energy seems to be without exciting cause, and without perceptible diminution. If radiant energy, may not perfumes, which have been regarded as material emanations, be of the same character, and the rose emit rays that will affect a properly sensitized plate?

This hasty résumé of some of the leading facts in the growth of a branch of science, the history of which practically begins with that of the Institute, to which the occasion more naturally invited than to a display of its achievements, would find its highest justification in the enumeration of its applications. But a very few must suffice. In scientific investigation the eye has been replaced in so many cases by the camera, for observation as well as record, that we begin to inquire what is left for visual observation. This is not for the relief of the eye, but because the photographic plate has so much wider range in time and space. It is capable of observing the instantaneous, and yet of looking without wearying, but with cumulative effect by the hour to catch phenomena to which the eye, with its best aids, is hopelessly blind. It has even been said by an eminent astronomer, that it has added to observing power as much as the invention of the telescope. It has, in fact, revolutionized astronomy. Beginning with the moon, with which perhaps least has been accomplished, total eclipses of the sun have yielded up long desired information, otherwise unattainable, so that they, by comparison, approach the character of worked-out fields. Automatic daily observations of the solar surface, with the details of its

spots, promise data for determining effects upon terrestrial climate. Nebulæ have been discovered, their form, details and conditions revealed, and fainter extensions, vaster than could be conceived, added. Comets have exhibited wonderful transformations, distortions and internal movements utterly undiscoverable by the best telescopes alone. Asteroids so numerous leave the record of their existence in trails upon the plates that, as has been said by Professor Barnard, they are turned adrift again unless they show some striking peculiarity of orbit. Meteors record their paths on which rests the expectation of precise determination of the radiant. Combined with the spectroscope, binaries of shortest periods are detected, variable stars not only discovered, but classified. The surmises of mathematicians in regard to Saturn's rings are confirmed. Runaway stars are caught. The Parisian astronomer that could not catch the satellite of Neptune with his telescope, could see it fixed on his photographic plate.

Photography and the microscope, too, have gone hand-in-hand with a more intimate sympathy even than that between the camera and the telescope. Among the earliest amateurs of highest character was a large percentage of experts with the microscope. It was in the decade following the founding of the Institute that the microscope began to assume something of its present character as an instrument of delicacy and precision. In 1831, the factory of Ross was established, and under the stimulus and coöperation of such men as Herschel, Airy, Powell, and more especially Lister, improvements in the optics and mechanics of the microscope were rapidly made, so that at the discovery of photography, microscopy had an entirely modern aspect, and it recognized at once a new ally. Dr. Draper immediately took micro-daguerreotypes. From this time the improvements in optical appliances urgently demanded by the microscopist were ably seconded by the photographer, and both combined were largely instrumental in occasioning the marked progress in practical optics, which, in turn, reacted to advance photography and microscopy. Even in the days of slow wet-collodion good work was done with the microscope, and even

stereo-photo-micrographs were taken by Professor Rood. The rapid dry-plate, sensitive to all or any desired colors, has nowhere contributed more to the advance of photographic practice than with the microscope. It has become to it only less the observing and recording eye than to the telescope. The intimate connection between the microscope and the camera is also well exemplified in the Institute, where the gifted Zentmayer gave the world its best model for the microscope, and the lens which bore his name long filled a place entirely its own in photography, and when the Government placed the administration of the total eclipse expedition of 1869 in the hands of Professor Morton, then Secretary of the Institute, it was unnecessary to seek further for the complete solution of the then new practical optical questions involved in such an enterprise.

In chemistry, Dr. Crookes, by aid of photo-spectroscopy and orthochromatic plates, has added the metal monium to the list, with its characteristic lines far out in the ultra invisible light, in the phosphorescent glow of yttria under molecular bombardment in vacuo. Meteorological science is enriched by photography. It is pertinent to mention the interesting contributions of W. N. Jennings, of the Institute, to the study of lightning discharges, and the work of C. Francis Jenkins in the conversion of a scientific toy into the phantascope, which has found its extension in the kinetoscope, and which earned for him the Cresson medal of the Institute. The kinetoscope, with its miles of photographic films, as exhibited first by our H. R. Heyl, has found applications unanticipated in recording the movements during a solar eclipse and of growing plants, and has gone to the front with the army in Africa. In the industries the applications of photography are of infinite variety in character and importance. It is proposed to furnish cards for the Jacquard loom, and thus make tapestries commonplace. It will furnish water-marks for paper capable of 100,000 impressions. It reproduced the Encyclopædia Britannica at one-third the cost of type. It preserved the valuable MS. copy of Century Dictionary, which was practically uninsurable, in miniature form against loss by fire. It may, in the

future, in the same way, find a place to economize shelf-room in our libraries by compressing books that are seldom or never read. Its applications are well known in the copying of inscriptions, even in dark interiors, in the preservation and duplication of valuable documents and papers, in the detection of forgeries, especially by the method of composite photography as developed by Dr. Persifor Frazer, in the furnishing of legal evidence in general, in the detection of criminals, etc. In Canada, 50,000 square miles have been platted by means of the photo-theodolite. In the late war the camera went to the front, and has furnished invaluable records Apropos to this, it is only necessary to recall Capt. Wise making exposures whilst charging up San Juan Hill. In the present African war it promises to play an important part in reconnoissance through the telephoto apparatus that accompanies the British forces.

In its purely commercial aspects this subject is one of growing importance. The demands, at present great, are rapidly increasing with new applications and expansion of those now in use. Outside of the industries consuming photographic goods there are at least 1,500,000 amateurs in the United States, generally regarded as gross consumers. The industries supplying photographic wants are necessarily of the most varied character. Companies supplying them are continually increasing their plants. It is difficult to get at the amount of business and profits, but the published statement of one company originating in America, now in England and America, announced a dividend of 20 per cent. in December last, with repeated interim dividends, on a capital of $8,000,000. Other companies show similar prosperity. One article, largely consumed, may be particularly mentioned, which America does not seem able yet to produce of best quality, namely, paper, and it is well for manufacturers to remember that in photography only the best of everything is good enough.

Mining and Metallurgical Section.

THREE-QUARTERS OF A CENTURY'S PROGRESS IN MINING AND METALLURGY.

BY CHAS. KIRCHHOFF,
Editor *The Iron Age*, New York.

[An address delivered in Convention Hall, National Export Exposition, Wednesday, October 4, 1899, on the Occasion of the Celebration of the Seventy-fifth Anniversary of the Franklin Institute.]

It is with swelling pride that we may pause to look over the achievements in mining and metallurgy during the past seventy-five years. Within that brief span, which, as we reckon generations, has extended over only two and a half, there have been created our great industries of to-day. Our country may look back over what has been accomplished with satisfaction, even if we admit frankly and fully that we have been blessed with extraordinary resources. It may seem almost crude to gloat over mere arrays of figures, and the reproach, occasionally made, that we worship quantity unduly, has some justification, yet the record is an amazing one, nevertheless. A more serious criticism is that we have been prodigal of our heritage. Let it be admitted that we have been, and are even still, in some respects, wasteful and extravagant. Much of that reproach vanishes, however, when the conditions are taken into account. In the arts, in engineering and in manufacturing, after all, it is the balance-sheet which rules, and, from an economic point of view, waste may be not alone justified, but be actually imperative.

It is difficult to measure progress, qualitatively, in branches like mining and metallurgy. It is expressed in the more complete utilization of the natural resources, as in the increase in the total extraction of the contents of a coal bed. It is in evidence in the form of a capacity to utilize bodies of ores, lower and lower in grade. It is proven by ability to produce from rebellious, or impure ores, metals nearly chemically pure, and commercially available for a

wider and wider range of consumption. It finds expression in the disappearance of the supremacy of the brand, only too often the creature of fortuitous circumstances. It is measured by an expansion of markets which may be due to the fact that technical progress has proceeded more rapidly in one country than in others.

For these reasons a simple enumeration of statistics of production only partially reflects the development of an industry. Yet that in itself shows a record of which we may well be proud.

Practically seventy-five years ago our greatest mining and metallurgical industries were in their infancy, and many were not even started. We had only begun to mine small quantities of anthracite coal. We were producing iron, but had at an earlier date been relatively more important as an iron-manufacturing nation. Silver, copper and lead were made in irregular, very small quantities. Zinc was not produced, and the gold output, with the Georgia gold rush of 1828–1830, was about to begin. In other words, our mining and metallurgical industries were of so limited a character that, compared with the ancient operations of the leading European nations, they were insignificant to a degree.

While it is true that our miners and smelters rose to the occasion when they were called upon to meet special conditions, the general fact is apparent, from a study of our development, that we first copied and then adapted the methods approved by experience in Europe. We were forced and did create hydraulic mining to collect the gold from alluvial deposits. We developed the preparation of anthracite for the market. We had nothing to guide us in handling the copper rock of Lake Superior. The Washoe process was worked out to treat the silver ores of the Comstock lode. There were few precedents for methods in the petroleum industry, and had to learn by ourselves how to collect, distribute and utilize natural gas. But Cornish, Welsh and English miners long controlled the working out of our mining methods. German and English metallurgists guided our first steps in beneficiating our more complex silver, lead and copper ores.

One of the most brilliant reports on the state of the art ever written, that of Abram S. Hewitt on the Paris Exposition of 1867, is a confession of superiority of European methods in iron manufacture, which is almost staggering to one who reads it in the light of the present day. I cannot help feeling that the recognition of our indebtedness to European practice in the earlier days should be insisted upon, since it is becoming altogether too common to assume that we are the chosen people so far as the mechanic arts are concerned. Many of you have, undoubtedly, like myself, encountered that feeling in such places that the fear of the danger of overconfidence is naturally aroused.

A striking fact is the growing interdependence of the various branches of the mechanic arts as contrasted with the conditions prevailing seventy-five years ago. The one relies upon the other, not alone for its products, but is aided too by suggestions and support. The metallurgist's progress is accelerated by the mechanical engineer, and the latter looks to the former for increasingly strong and reliable materials. The electrician has greatly widened the capacity for improving methods on the part of the copper producer, and in turn is under a debt to him. The cheapening of fuel, due to the efforts of the coal miner, and the achievements of the rail-maker, are returned in kind by the railroad builder, who has taught both much of value in transporting materials. Thus, all are shoulder to shoulder in the march of progress, mutually helpful and united—all-powerful.

To a constantly-increasing degree pure science, primarily in search of the truth for its own sake, sheds its searchlight along the path, and has become a closer and more valued ally year by year. Many of us will recall how the majority of active workers looked askance at this meddler, preferring to allow their own fancy full sway whenever they stopped to seek for causes or explanations. We may sometimes become impatient when the laborious and apparently hypercritical methods of the scientist do not more promptly clear an obscure point, or furnish us with a suggestion for suc-

cessful new lines of work, but the day has long passed when we treated research with grudging respect, if not with open hostility. No one is now readier to acknowledge his indebtedness to the chemist or the physicist than the manager or the practicing engineer. The fear is disappearing of impracticable science on the one hand, and of unscientific practice on the other. And foremost in the work of harmonizing both in this country has been the time-honored body whom you, Mr. President, represent. The splendid array of the volumes of the *Journal* of this Institute is, in itself, the greatest monument to the man whose name it bears, and to those who have labored in pursuing in his spirit the promotion of science and the arts as a means toward promoting the happiness of mankind.

MINING.

With the widespread search all over the world, and the increasing number of trained observers, there has been an enormous accumulation of observations and data relative to mineral deposits. In the case of bedded deposits, the relations between mining development and economic geology have become closer and closer. But, on the whole, it cannot be said that this branch of science has given much direct aid to the metal miner. The systems of extraction have not undergone any radical improvement. On the whole, they are modified more frequently to meet more closely local conditions. It is rather in the work of excavation proper that progress has been most striking. It was J. J. Couch, a Philadelphian, who, in 1849, patented the first percussion drill ever made. Herman Haupt experimented with rock drills at the Hoosac Tunnel, from 1856 to 1861, while the first drill tried in mining was that of Schumann at Freiberg, in 1857.

Colladon had proposed to use compressed air to work drills as early as 1852, but general attention to rock drills driven by compressed air was attracted by their employment at the Mont Cenis Tunnel in 1861, the plan to adopt them having been approved in 1857, as the result of Sommeiller's work. Quickly following upon the start thus made

by power drills, came the introduction of high explosives. Nobel first applied nitroglycerine in 1863, and its use was begun in 1866 at the Hoosac Tunnel. A year later Nobel introduced dynamite, and since then power drills and high explosives have wrought a complete revolution in mining, by increasing the speed of development and extraction, by very greatly increasing the efficiency per man employed underground, and by heavily reducing the cost. By constant improvement in design and detail of both compressor and drill, machines have been created which have a wonderful life and efficiency, considering the adverse conditions under which they are expected to operate. What the defects in design in the early days meant is illustrated by the fact that in 1864, in the Mont Cenis Tunnel, it took an equipment of seventy Sommeiller drills to keep eight steadily at work, and in 1867, 200 were needed to maintain sixteen in actual operation.

The mechanical engineer and machine builder have given their powerful aid, too, in improving pumping and hoisting machinery. The simple and effective American direct-acting pump has done valuable service to mining, although for heavy service and large quantities of water it is giving way to more elaborate engines. In hoisting appliances, for deep mining we long remained behind European practice, our shallow mining not calling for heavy engines. During the last decades, however, some splendid equipment in magnitude, in speed and in economy of operation has been designed in this country, some of the greatest of these engines having been built in this city.

Underground traction has undergone far-reaching changes. Wire-rope haulage was introduced into collieries long before San Francisco led in surface cable traction, and in this country pneumatic and electric haulage were very promptly adopted and very rapidly developed. These, however, are only recent achievements, progress in underground haulage having been very slow for decades.

In timbering the Comstock square set was a characteristically American creation to meet exceptional conditions, and it is true that the preparation of mine timbers above ground by machinery was first practiced in this country.

For a long time the concentration of ores was neglected, simply because in many remote sections in the United States it did not pay to turn to mechanical dressing and because the oxidized surface ores, easily smelted, did not offer opportunities. An exception must be made of the Lake Superior copper region. There the Ball steam stamp quickly superseded the time-honored battery. Subsequently, Leavitt reduced the steam consumption by compounding, and more recent practice has proven that the spring foundation is not equal to the solid anvil in bringing out the highest efficiency. Ore concentration has been well developed in later years in Southeastern Missouri, and the low-grade lead and copper camps of Colorado, Utah, Idaho and Montana.

It would be a serious oversight, in dealing with the treatment of ores, to overlook the enormous influence which the introduction of the Blake crusher has wielded in the efficient handling of rock. Nor should later types of crushers, like the Gates, be overlooked.

An example of steady progress in crushing apparatus is furnished also by what is known as the California stamp mill. Every detail has been watched and worked out for decades, and a number of efficient self-feeding appliances have been added, until to-day there are enormous plants pounding away year in, year out, without any intermission, with merely a crew of inspection to represent the labor account.

It seems certain that the part which the rock drill has played in general mining is destined to be paralleled in coal mining by the modern coal-cutting machinery. The difficulties inherent in handling mechanical apparatus in low rooms may account for the fact that progress has apparently lingered so far behind in this field. In Europe, as well as in this country, inventors took hold of the problem in the fifties, but little headway was made for many years. It is only quite recently that machinery for this purpose is being introduced with a rush. Among the pioneers were Harrison with a pick machine, and Lechner with a cutter-bar machine. All the earlier types were driven with compressed air, and it was not until 1889 that electricity was applied to

the Jeffrey cutter bar machine, since superseded by the electrically-driven chain breast machine. How rapid has been the development of this branch of work in this country in recent years is shown by statistics compiled by E. W. Parker, of the United States Geological Survey. In 1891 6,211,732 tons of coal were mined by machines representing 6·66 per cent. of the whole. In 1898 the tonnage had jumped to 32,413,144 tons, or 20·4 per cent. of the whole. It is not too much to say that, from an economic point of view, this is the most far-reaching and significant recent development in mining.

A splendid achievement in mining was that of handling auriferous sands by hydraulicking. I do not remember ever having noted in our literature any definite data which might fix the credit for this upon any one man or group of men. The date is placed at about 1853, and in those stirring times, so soon following the discovery of gold in California, probably no record was left. The further stages of its development are coupled with the names of a number of inventors of nozzles and many ingenious hydrodynamic and hydrostatic contrivances, and in its greater days, before the anti-debris laws in 1882 cut off the work, bold and splendid engineering work was done in connection with these undertakings.

In more recent times some very thorough work has been done in one branch of ore dressing, and that is, in magnetic separation of iron ores. A number of American inventors, among them Ball & Norton, Wenstrom, Wetherill and Edison, have labored to utilize the lower grades of magnetites in the Eastern States. The problem of cheap and effective crushing involved has been carefully studied and brought out new ideas, but economic conditions for a while pushed the whole undertaking into the background. Recent events point to fresh opportunities in this direction.

METALLURGY.

Gold.—In the metallurgy of the precious metals marked progress has been made, although no really revolutionary methods have come to the front until the present decade

brought the cyanide process. In gold extraction the improvement in the California stamp mill, largely mechanical, has already been alluded to. There have been added, in the amalgamation process, some ingenious contrivances, but it was not until the experienced chemist drove out the horde of so-called "professors" and charlatans that the treatment of auriferous concentrates and pyrites was a success. The chlorination process, together with the improvement in the design and operation of the batteries, and the introduction of the Frue vanner and machines of its type, has rendered possible the profitable treatment of very low grade ores. These are to-day prosperous enterprises based on a yield of $\frac{1}{10}$ of an ounce of the yellow metal to the ton of rock—a quantity so minute that no gold is visible in the ore, week in, week out.

The chemist again has intervened in recent years. While the solvent power of cyanides on gold was known early in this century, it was not until the later eighties that the McArthur-Forrest process made that method practicable by utilizing the fact that zinc shavings may be used as a precipitant.

For the treatment of more complex ores there was developed relatively early, at the Argo Works in Denver, a series of methods dependent upon the employment of copper as a carrier, and more recently pyritic smelting is gaining ground. It is based upon the treatment of sulphide ores in the blast furnaces, so that a considerable part of the heat produced by their oxidation is utilized in their fusion. Small quantities of lead or copper serve as collectors of precious metals.

Silver.—Although the patio process of amalgamation was invented in 1557 by Bartolome de Medina, at Pachuca, followed in 1590 by the cazo process of amalgamation invented by Alonzo Barba, at Potosi, no real improvement followed in the succeeding centuries. On the heels of the discovery of the Comstock lode in 1859, by O'Reilly and McLaughlin, came the invention of what is known as the Washoe process of amalgamation, by Almarin B. Paul and James Smith. On the oxidized and chloride ores of the surface

it did admirable work, but, as the more rebellious material below drainage lever appeared in growing quantities, auxiliary operations required growing attention, the Augustin, Ziervogel and Patera processes, brought out from 1843 to 1858 in Europe, having been used only locally here. It was in the direction of improving the chloridizing roasting that metallurgists sought and found a solution of their troubles. Brueckner, Stetefeldt, Howell, O'Hara and others did admirable work, but with the steady improvements in lead smelting, increasing quantities of the rebellious silver ores were diverted from the amalgamating mills to the smelters, and now silver milling has shrunk to a secondary place.

Lead.—Although lead mining was begun as early as in the days of Law's famous Mississippi Company, and Mine La Motte, in Southwest Missouri, still in active operation, was discovered at that time, yet production did not develop seriously until late in the twenties. It attained about 10,000 tons per annum in 1833. With the rich and pure ores the Scotch hearth served admirably and remained the standard method until the discoveries in quick succession of the rich ore bodies of Eureka, Nevada and of different camps in Utah, late in the sixties, led to the copying of German blast furnace practice. Arents, Eilers, Hahn, Grant and others socn introduced improvements, Arents' siphon tap being a very important step forward. Water jackets appeared and a thorough scientific study of the chemical composition of slags led to more regular and cleaner working, and the collection of flue dust assumed growing importance, Iles, of Denver, doing conspicuous work in this direction. Charcoal as a fuel gave way to coke—the quantity of lead in the smelting charges needed to cover the precious metals was steadily crowded down under the pressure of a scant supply of lead-bearing ores. With the steady development of the railroad system of the Rocky Mountains, dry ores carrying little or no lead became available in larger quantities, and to-day American lead smelting plants are models for the world.

As an incident of progress in another direction may be mentioned the Bartlett process, for the direct production of

white oxide for paint in successful operation at Joplin and at Canon City. In lead desilverizing and refining, a modification of the Pattinson process, invented in 1833, found only a passing application. Soon after the argentiferous base bullion of the Rocky Mountains made their appearance, the Parkes zinc process, invented in 1852, was first introduced at the Balbach works at Newark, and the most important improvement in it was that of the Faber du Faur furnace for distilling the rich zinc alloy. Since then progress has taken the direction of economic handling of large charges and the introduction of labor-saving appliances.

Copper.—Although some copper was mined along the Atlantic coast at a number of points in the eighteenth and during the earlier part of the present century, it was not until the gradual opening up of the Lake Superior region from 1845 onward that it attained the dignity of an important industry. Curiously enough, it was in the same year that the smelting industry on the seaboard was started by the Revere Copper Company and the Baltimore and Cuba Smelting and Refining Company; both depended almost entirely upon foreign supplies of raw material. These flourished for about twenty years, and then collapsed or led a precarious existence until domestic supplies of furnace material from the Rocky Mountain region caused their revival. To-day our tidewater plants are among the great works of the world, and have begun to again draw heavily from foreign sources. Thus, Australian black copper comes to us *via* London for treatment, to be returned to the European markets, and Chili bars are making the same journeys. Metallurgically, there is little to remark concerning the development in the treatment of the native copper of the Lake region, which held sway in the markets for so many decades. The time-honored methods of refining continued with little change, although effort was made to introduce the Siemens open-hearth furnace.

A new era began with the opening up of the oxidized deposits of Arizona and the ores of the Butte district. In the former the water-jacketing of the furnaces was one of the first successful steps, and a general improvement of practice

followed quickly. In the Butte district a good deal of tentative work was done in concentration, in roasting and in smelting in reverberatories and in blast furnaces. The Brueckner, Brown and Wethey roasting furnaces were adopted, and the Manhes process of bessemerizing, invented in 1883, in France, was first introduced at the Parrot works. The practice has been improved very rapidly, and now the remelting of the matte is being superseded by direct transfer from the furnace to the converter. Almost simultaneously came the electrolytic process of separating the precious metals, in which very rapid progress has been made, and which, coupled with the bessemerizing, an economic revolution has been effected, not alone in cost of production, but also in the direction of furnishing a high-grade metal from impure ores.

Iron and Steel.—And now we approach the greatest of all metals, iron, in the development of which this State has had so conspicuous a share. It would be presumptuous in me to even sketch its course, who have been a mere onlooker during the past twenty-five years, when there is with us one who has lived through its most glorious period and has had so commanding and conspicuous a part in the great deeds of American iron-makers and engineers.

After all it was not until the days when John Fritz became a leader that the marvellous development was initiated. Remember that it was not until 1839 that anthracite was used in the blast furnace, and that six years later raw bituminous coal was tried in this country as a furnace fuel. You must recall that boiling was only introduced in 1848, that our modern steel-making processes did not really occupy a commanding position until late in the sixties, and you will realize that the great period of the iron industry is really concentrated in the last thirty years.

One fact perhaps you will allow me to dwell upon, and that is, that the Bessemer process really forced a recognition of scientific work upon the attention of the practical ironmaster. The chemist very soon became a part of the force of the steel works, and somewhat later of the furnace plants, who were anxious to have them as customers for pig iron.

Not that chemical research had not long since been directed to metallurgical operations, and not that a few did not indulge in speculations as to the scientific causes of observed phenomena.

It was only lately that I came upon striking evidence of that in David Mushet's classical work on "Iron and Steel," printed in 1840. The following passage is characteristic:

"The quality of air during the summer months becomes much contaminated from combustion; by holding in solution a much greater quantity of moisture, the abundance of nitrous particles may also diminish the usual proportion of oxygen. This will account for the inferior effects of combustion, both in common fires and in the blast furnace. It will also in a measure tend to solve the curious phenomenon of pig iron taking up less carbon in summer, although reduced with a superior quantity of fuel. The air discharged most probably contains less oxygen, yet the metal is much less carbonated than at other times when contrary proportions exist. Most probably the deficient carbon is carried off by dissolving in hydrogen, forming a constant stream of hydrocarbon gas, while the oxygen that is free unites to the iron, and while it reduces the quality, at the same time the quantity is reduced by a portion of the metal being lost in the scoria."

It is thus that one of our pioneer metallurgists seeks an explanation for the fact that furnaces are apt to make off grade irons in summer—a phenomenon which is said to have become a marked one in this boom year 1899.

Recent history in the branches of the mechanic arts records many instances of the powerful aid which theoretical investigation has offered to them. One of the most conspicuous was von Ehrenwerth's heat calculations in connection with the basic Bessemer process, which established the role which phosphorus is capable of playing as a substitute for silicon as a heat agent. Nor should that promising field be overlooked which microscopic investigation holds out. Possibly in that respect twenty years since our groping may appear not unlike that which Mushet's appears to us now.

But progress during the last seventy-five years has been

pushed along lines as important in their way, as the cheapening of product, or the raising of the standard of quality. Like in other industries, the captains of ours have displayed increasing care of their armies of men. It has become an axiom with every enlightened manager that every means which shall render more satisfactory the surroundings of the workers is bound to tell upon the results of their labor. Compare our modern plants with those of former decades, of which some even survive now, and note what attention is paid to make the conditions under which manual labor is performed as tolerable as the circumstances will permit. There has been a tremendous improvement in this direction, and it does not lessen the achievement when we frankly acknowledge that it is largely due to the recognition of the fact that progress in this direction pays handsomely.

Let me go a step further, and that is, that the crowning glory of the efforts to improve our mining and metallurgical industries has been that they have contributed their full share to the development of this materialistic age. They have helped to bring within the reach of an ever-growing circle of people not alone the necessities, but also many of the comforts and some of the luxuries of life. Let me confess that it seems to me the greatest and most commendable of achievements to raise ever so little the mass of humanity in civilization, and that is what progress in the mechanic arts during the past century has accomplished in a striking manner. Start the masses on a higher plane—level them up. The great genius may not tower so far above them as once he did, but that is again in harmony with our democratic institutions. Let there be an increasing equality of opportunity, even though it makes the struggle fiercer and fiercer, if only public conscience will demand with sterner emphasis that the means for achievement be fair.

It was the keynote of Franklin's life that all his thoughts and all his endeavors were directed to making his work of benefit to the human race. Although those who have labored in our fields may not have done so as consciously or as deliberately as he, the fact is that progress in mining and metallurgy has powerfully contributed toward that end.

THE DEVELOPMENT OF IRON MANUFACTURE IN THE UNITED STATES IN THE PAST SEVENTY-FIVE YEARS.*

BY JOHN FRITZ,
Bethlehem, Pa.

[An address delivered in Convention Hall, National Export Exposition, Wednesday, October 4th, on the Occasion of the Celebration of the Seventy-fifth Anniversary of the Franklin Institute.]

I have been requested by your President, Mr. Birkinbine, and also by Mr. Christie, Chairman of the Mining and Metallurgical Section of the Institute, to give some reminiscences concerning the progress that has been made in iron and steel metallurgy in my lifetime and during the lifetime of the Franklin Institute.

This being the last year but one of the century that has done so much to change the face of society, and for the betterment of mankind, it will be interesting to take a brief retrospective view of the events that have taken place during this remarkable period, and in doing so we witness the most wonderful progress that has been made in the advancement of the arts of science and civilization, all the effects of which are far-reaching.

In the very front we see the phenomenal progress that has been wrought in all the various branches of manufac-

*[INTRODUCTORY.—It was my intention to have given a brief account of the early experiments with the Bessemer process at Cambria and Wyandotte, and also a brief notice of the earlier works that went into the business; I soon found, however, that it was not possible to do so in a paper such as I was called on to read; and, besides, Mr. Wm. F. Durfee and Mr. R. W. Hunt, who each by turns had charge of the experiments at Wyandotte, have already put the general results on record. Consequently, I will confine myself to such a paper as I was called to give—some personal reminiscences of my connection with the manufacture of iron and steel, which is unfortunate for me, as I would much prefer to tell what others have done than what I have done myself. But, as I was asked to do this by the officers of your society, and did not seek the honor, I beg you will, as far as possible, excuse much that will doubtless seem egotistical, and ask you to bear in mind that what I have to say is only a general history of the early developments of the iron and steel industry in this country, with which others also had much to do.—J. F.]

ture in all parts of the civilized world. We look again and find that the manufacture of iron is in the lead, and that the United States comes in for a large share of this all-important branch of manufacturing industry, which is the advance guard of civilization, one which has done so much to build up this country and served her so well both in peace and in war.

While I have not been asked to say anything about matters beyond the date of my own experience or the life of the Institute, it seems necessary, however, that a brief allusion should be made to the first puddling furnace and plate mill that were erected, in order that the great advance that has been made in this branch of the manufacture may be more fully appreciated.

The first puddling furnace in this country was built at Plumsock, on Redstone Creek, about midway between Connellsville and Brownsville, in Fayette County, Pa., in 1817. A flood caused the partial destruction of this mill. The machinery was subsequently removed to Brownsville. In 1819 a rolling mill was built at Pittsburgh in which there were four puddling furnaces. This mill was accidentally blown up, and permanently dismantled in 1829, and the machinery was taken to Covington, Ky. Both enterprises thus seem to have ended in disastrous failures.

About 1810 Isaac Pennock built a rolling mill (at that time called a "slitting mill") near Coatesville, in Chester County, Pa. In 1816 it came into the hands of Dr. Charles Lukens, a son-in-law of Isaac Pennock, and was operated by him until his death in 1825. It was during this period and on this mill that the first boiler plate was rolled in this country. The blooms were heated on a grate fire and the rolls were driven by an old-time undershot water-wheel. When a boy I heard the older men say that the mill was often short of power, and frequently all the workmen would run and get on the buckets and tread with them, in order to prevent a stall which would have caused fire cracks in the rolls, and, sooner or later, a broken roll. This being before the days of railroads, coal was hauled from Columbia, thirty-five miles distant, and the plates were teamed to

Philadelphia, thirty-five miles away, and were shipped without being sheared. A notable circumstance about these works is the fact that they have always remained in the family of Isaac Pennock, and are now operated by his descendants of the fourth generation.

What I have now said will be sufficient to give you some idea of the condition of the trade at that time, and will enable you better to appreciate the great improvements that afterwards were made; and also brings us practically down to the birth of the Institute in 1824.

From 1824 until 1836 but little progress was made in the way of marked improvements. During the thirties there were some puddling furnaces built, to puddle run-out or refined pig metal, and eventually they got in the way of using some close grain pig iron in connection with the refined metal.

In the early forties puddling began to come into general use, but only close iron was used. In the years 1844–45 the manufacture of rails commenced. This at once gave it the leading position in the manufacture of iron, which it held until it was beaten by the Bessemer process, to which I shall refer again.

About this time the manufacturers' trouble begins. The demand for puddlers soon exceeded the supply, and they thought they ought to have things their own way. Up to this time the old-fashioned Welsh hammer was the only mode in use for putting the puddled ball in shape for the rolls. The hammerman or "shingler," as he was called at that time, was the king bee, and when he went wrong, as he frequently did, the puddlers had to quit work until such a time as Mr. "Shingler" was ready to go to work, which sometimes required several days; and when at work woe be unto the puddler who might happen to be on bad terms with him.

The hammer striking a uniform blow no coaxing could be done; consequently great skill was required during the first few strokes of the hammer to keep the ball in such shape that it could be edged and upended in order to get a good-shaped and compact bloom. Should the "shingler"

fail in this, which he could and at times did, and that without any apparent intention, then a row was started which sometimes ended in a fisticuff, as we had bullies in those days as well as now, but not so well trained, and the rules of the ring were not such as they are to-day; if they had been, they would not have been strictly adhered to.

The next improvement in this line was the introduction of what was known as the "crocodile" squeezer, which was entirely unlike the hammer in every way, and it was so easily worked that almost any of the puddlers could put their own work in shape; but, unfortunately for the manufacturer, they could coax a ball into shape that was not properly worked in the furnace. So, while this was entirely satisfactory to the puddler, it was very unsatisfactory and unprofitable to the manufacturer, with the result that there was constant bickering between the employers and employés; a condition of affairs that should not exist.

Next came the "Burden" and "Winslow" squeezers; the latter was used for a time, but finally the "Burden" came into general use, and is to this day as nearly perfect a machine for the purpose intended that has ever been devised. Not alone on account of its simplicity in construction and the perfect manner in which it does its work, but because, also, it establishes justice between the ironmaster and the workmen from which there is no attempt to make an appeal. When a ball would break, the workman, without saying a word, gathered together the pieces and took them back to the furnace and worked them into a proper condition, and in the end the squeezer proved to be the puddler's friend. Notwithstanding all its good qualities, its introduction caused strife in practically all the mills that introduced it down to about the year 1856. Some of the strikes were long and bitter, and many incidents might be recited in relation to its introduction, some amusing, some ridiculous and others revengeful. However, soon after the system came in general use, an armistice was agreed upon, which finally resulted in a treaty of peace, which was advantageous to both parties.

In or about the year 1848, boiling came into general use,

which was a great improvement, and puddling soon became the all-important branch of the great iron industry of the country, and continued in the lead until it was overtaken by the almost magical invention of Sir Henry Bessemer, to which I shall refer later.

Until 1840 all the pig iron produced in the United States was made with charcoal. My first connection with a furnace dates from 1839. It was driven by water, a wooden blowing-cylinder connected with the crank by a wooden beam. The crank, the journal and the wings that were fitted in the end of the water-wheel shaft to carry the wheel and to drive the blowing-cylinders. Neither of the journals were turned off, but were put to work just as they came out of the sand. It was blown by an open tuyere. The whole plant was of the crudest construction. The weekly make was about sixteen to twenty tons. It was placed against a bank, level with the tunnel-head, so as to avoid hoisting the material up. This was about the character of the furnaces in general use at that time.

I was sent there as a "cub" to put up a belly-pipe which was made at the shop in which I was learning my trade. When it was put in place it was, as I remember, about six or eight inches too short, and I supposed somebody had made a mistake in the length. The founder was a consequential-looking man, and quite stout, with a blue flannel shirt and his "pants" held up by a rather broad leather band buckled around his body, somewhat in the order of many we see to-day, but was not gotten up in the same style. He said rather brusquely that "it was all right." The pipe was connected at the rear end to the main pipe by a short leather connection, which I was told was to allow the belly-pipe to swing out of the way so that they could get the cinder out.

This was the general condition of the furnaces until 1840, when Mr. David Thomas, since affectionately called "Father Thomas," made the first anthracite iron in a commercial way that was made in this country. This was the commencement of the phenomenal development of the blast-furnace practice that has taken place in the latter part of this century.

We left the rolling mills in 1824 in a very crude condition, and there was no marked improvement in them until the manufacture of rails commenced, which, as already mentioned, was about 1844. But even at this time the plans of the mill and manner of building practically remained the same, being geared, and it seemed to me that the general impression amongst the rolling mill proprietors was that the more wheels they could get in the better was the mill. Down to this time the carpenter or millwright had largely the say, consequently wood was much used. The shafts were generally made square, and the fly-wheel and gear-wheels were secured on them by the use of wooden wedges, into which other thin wedges of iron were driven. No matter if the foundation was built of wood or stone, a large piece of timber was placed on top, to which the housings were secured; the idea being that it was essential that the train should have some elasticity in order to take the shock off the machinery, thereby preventing breakage.

After the manufacture of rails commenced in 1844 more rigid and better workmanship was required. The mills, as heretofore, were all geared, but the carpenter and millwright were superseded by the machinist. The shafts were now turned up, wheels were bored out, and the mill all fitted up in a more workmanlike manner.

From 1845 to 1856 there were but few improvements made, either in machinery or the manner of rolling, except the introduction of the rail-straightening machine which took the place of the sixty-pound sledge and a special man to handle it. When he wanted a rest the works had to come to a standstill until such a time as he was completely rested, sobered up, or restored to health, as the case might be.

The year 1857 is a memorable period in the history of the manufacture of iron. As before stated, in 1844 the forge carpenter and millwright were superseded by the machinist, who now comes to the front as a mechanical engineer, not full fledged, but with an amount of knowledge gained by experience which qualified him for the important duty which awaits him.

As I have already said, the year 1857 was a memorable period in the history of the manufacture of iron. Down to this time all the rails were rolled on a two-high train, the pile being passed back over the top roll, which meant a great waste of time and loss of heat. When the flanges once began to-crack, which was one of the serious troubles, being all the time rolled in one direction, it greatly aggravated the difficulty. The result was that when an imperfection occurred in the flange, the trouble increased with each pass through the rolls, and so extended that it was a common occurrence for the flange to tear off the whole length of the rail and wind around the roll, forming what, in rolling mill parlance, was called a collar, which very generally ended in breaking some part of the train and often the roll.

The iron was frequently both red- and cold-short and all other shorts, and in addition to this would stand but little heat, consequently the end of the pile which entered the roll first would split and open out like the mouth of an alligator. Then, of course, it would not enter the rolls without force, which was applied with the buggy, using it as a battering ram. After making several vain attempts to get it to enter the rolls it very frequently had to be turned end for end. The loss of time taken up in going through all this was such that it was almost an impossibility to get a perfect rail. Had it not been for the use of putty, oxide of iron and the absence of inspectors there would have been but few rails shipped.

In order to get over the difficulty of the flanges tearing off we went to quite an expense. Some iron of a better quality was used for the flanges, which, in a measure, gave some relief in that direction. But the iron being much stronger, required more heat and greatly increased the difficulty of opening the end of the pile in the first few passes. We were now in a sad dilemma, and something had to be done. I was sick at heart, and had it been manly I would have run away.

But, during all this time, I was giving the subject much consideration, and had fully made up my mind that, if a

three-high mill could be made to work, the difficulties could all be overcome; I, besides, had made up my mind that it was the only proper way to roll iron.

I was now prepared to suggest the building of a three-high mill, which I did; and the suggestion was met with a rebuff, which was not unexpected. They said in substance: "It was a visionary scheme; it had never been done, and had it been practical it would have been done long ago." In reply, I told them something must be done or there would be a large funeral, and I did not want to be one of the mourners. The subject was then more seriously taken up by the company, and it was suggested that a better ore should be secured as a mixture to improve the quality of the iron; but the location of the works was such that a suitable ore could not be got at a price that would permit it to be used as a rail mixture, so this course was abandoned.

The company now began to see that it was necessary that something should be done. The directors called a meeting and, after consultation with some practical iron men, decided to put up a geared two-high mill, and by greatly increasing the speed of the rolls, the rail would be finished in much less time, and consequently at a higher heat, which would prevent the serious trouble of rough and torn flanges. After some pertinent discussion, I was ordered to build a new mill, two-high, geared. As my patience had become exhausted, and being thoroughly disgusted and especially so with the geared mill, I most emphatically said I would not do it, as two of the most objectionable features of the present system would still be retained. I was then asked what right I had to dictate to the company in regard to the policy they should pursue in the line of their business. I answered that I had no right whatever, but that I was thoroughly convinced that it would not remove the difficulty and in the end would be a failure and the result financial disaster. Being a young man and the only capital I had in the world being my reputation, and that being quite limited, I did not purpose placing it in danger where the chances were so unequal. This

interview ended in a suspension of hostilities, and for a short time nothing was said on either side. But the trouble in the mill still continued, and something must be done and quickly. Having already lost my reputation for complaisance and being considered as the most arbitrary of men they had ever met, I consequently concluded that I would do as I had been compelled to do before and many times since—assume authority and go ahead, which I did; and commenced work on the patterns. The drawings had already been practically completed.

After the pattern for the housing was well advanced, Mr. E. Y. Townsend, the Vice-President, came out to the works and I informed him of what I was doing, and again talked the situation over with him. He said nothing, but thought it proper to let the company know what was being done, to which I assented. In about a week, as I remember, he came to the works again. This time he was armed with a legal document opposing the spending of the money in the way it was being done. He handed me the document to read, which I did. I then handed it back to him and said nothing. He then asked me what I thought about it and the best course to pursue. In answer, I said: "You know the troubles we have had, and it is useless to go over them again, and you know my opinion, which is irrevocable." After some friendly talk on the condition and the importance of the change proposed, he said: "Go ahead and build the mill as you want it." I asked: "Do you say that officially?" to which he replied: "I will make it official." And he did so.

When I look back to that eventful interview, which took place on a Sunday morning long years ago, and recall to mind Mr. Townsend and myself, with evidences of failure on all sides, and surrounded by the gloom of future uncertainties, I cannot but feel it was the most critical period not only in my own career, but also in that of the Cambria Iron Company.

And here I wish to say that to Mr. E. Y. Townsend belongs the credit not only of the introduction of the three-high rolls, but also for a large share of the subsequent mar-

vellous prosperity of the Cambria Iron Company, which followed the introduction of the three-high mill and its many accompanying improvements.

The opposition to the three-high mill now came in from all quarters. The heaters on the rail mill were unanimous in their condemnation, and waited on the company to tell them what a direful failure it would be. Next I had to meet the combined prejudice of the ironmasters, who were a power at that time. Some of them would tell the managers that the whole thing was certain to be a failure. Next came my friends, in the trade and out of it, begging me to abandon what would surely prove a failure and blast my reputation for life. One of my dearest friends, with whom I had been employed for a number of years, came to see me and, if possible, to get me to change my plans. To them all I said "No, I can make it work, and it is the only plan that can be adopted that will save the company."

After all these years there is no person other than myself who can fully appreciate the trying position the managers were in. On the one hand, I was to build a mill on an untried plan, and absolutely refusing to build the mill they asked for, knowing full well that only in a small degree would it remedy the trouble, and that the money spent on such a plant would be thrown away. On the other hand, there was a strong party of stockholders, protesting in the most positive manner against going on with my plans, and notifying the managers that they would hold them personally liable for all the loss and damage that might grow out of their unwise action, as they considered this action to be, in adopting a new and untried method that was against all practice in this and the old country, for at that time we were expected to be followers instead of leaders. Notwithstanding all the opposition and trouble we had to encounter, the work on the mill was being pushed along as fast as it was possible. But there were many difficulties in the way. The most serious was the want of proper tools and facilities for doing the work. Many makeshifts had to be improvised, which all required time and labor. During all

this time there was much talk and speculation going on in regard to the final result, to all of which I gave but little attention.

At length the mill was completed, and on the third day of July, 1857, the old mill was shut down for the last time. On the fifth we commenced tearing the old mill out, as the new one had to be put in the same place. The work was pushed as fast as possible, day and night, but, as it was before the days of electric lights, the night work could not be done with the same expedition as to-day. At the same time everything in the rail department was remodelled and the floor line of the mill was raised two feet. On the 29th of the same month everything was completed and the mill ready to start. The starting of the mill was the crucial period.

In giving an account of the starting of the mill, I can probably do no better than quote from a paper written for a former occasion:

There were no invitations sent out. As the heaters to a man were opposed to the new kind of mill, we did not want them about at the start. We, however, secured one of the most reasonable of them to heat the piles for a trial. We had kept the furnace hot for several days as a blind. Everything being ready, we charged six piles. About 10 o'clock in the morning the first pile was drawn out of the furnace and went through the rolls without a hitch, making a perfect rail. You may imagine what my feelings were as I looked upon that first and perfect rail ever made on a three-high train.

And you may know in part how grateful I felt toward the few faithful men who were about me, and who had stood by me during all my trials and difficulties. Among these were Alexander Hamilton, the superintendent of the mill, and Thomas Lapsley, who had charge of the rail department, Wm. Canam and my brother George, all of whom have gone to their reward.

We now proceeded to roll the other five piles. When two more perfect rails had been rolled we were obliged to stop the engine for the reason that we were so intently

watching the rolls that the engine had been neglected, and, being new, the eccentric strap got hot and bent the eccentric rod so much that the engine could no longer be worked. As it would have taken some time to straighten the rod and reset the valves, the remaining piles were hauled out from the furnace onto the mill floor. About this time the heaters, hearing and seeing the exhaust of the engine, came into the mill in a body from the opposite end of the mill to where the rails were. Seeing the unrolled piles lying on the floor, they took it for granted that the new train was a failure; and their remarks about it were far from being complimentary. Mr. Hamilton, coming up and hearing what they were saying about the mill, turned around, and using language more pointed than polite, told them if they would go to the other end of the mill they would see three handsomer rails than had ever been made in their country, Wales. After getting the engine in shape, the day being Friday, we ran all day, and at night put the regular night turn on.

Everything worked well up to noon on Saturday, it being our custom to stop rolling at that time. About six o'clock in the evening Mr. Hamilton and myself left the mill, and on our way home congratulated ourselves on the fact that our long line of troubles and disappointments was now over. About an hour later I heard the fire-alarm whistle blow, and rushing back to the mill, found it one mass of flames from end to end. In less than one hour's time the whole building was burned to the ground, and a story was started that the new mill was a failure, and that we had burned the mill to hide our blundering mistakes. The situation of affairs on that Saturday night was such as might appall the stoutest heart. The product of our labors and anxieties lay there, a mass of black and smoking ruins, and the money that was so hard to get with which to build the mill was gone. The prospect was indeed gloomy, but there was one gleam of light amid all the darkness; and that, the pile of perfect and new rails, which, as Mr. Hamilton had said, had never been beaten in Wales, from which country the greater part of the rails used at that time came. Above

all, the mill had been tried and found to work magnificently, and it was these two facts that gave us all fresh courage, and enabled us to rebuild the mill.

The next day being Sunday, it was devoted to rest and to thinking over the matter. On Monday morning we commenced to clear up the wreck, all the workmen giving a full day towards it, and began the work of rebuilding. In four weeks from that time the mill was running, and made 30,000 tons of rails without a hitch or break of any kind, thus making the Cambria Iron Company a great financial success, and giving them a rail plant far in advance of any other plant in the world. This position they held, unquestioned, both for quality and quantity until the revolutionary invention of Sir Henry Bessemer came into general use.

In the construction of the three-high mill there were many changes and improvements on the old two-high mill. Up to this time the leading spindles had a groove cut in them to weaken them, so that if any extra strain should come on the rolls, they would break instead of the roll; and the couplings were made light so as to act as a kind of a safety-valve. Then there was a breaking box placed between the screw and the roll. If there was not one of these safety devices breaking each day, the pattern was made lighter. The result was that some of them were breaking several times daily, furnishing a constant source of annoyance. In building the new mill they were all made so strong that they were not calculated to break. The breaking box on top of the roll was made solid, as they were apt, when they gave way, to break the collars on the rolls, which should, if possible, be avoided. All these changes were stoutly opposed by the foremen and workmen of the mill. A few days before the mill was ready to start, the superintendent of the mill discovered that the breaking box was solid; he then got the pattern and took it to Mr. Lewis, the pattern-maker, and told him there was a mistake, that it was made solid. Mr. Lewis told him that it was made as the old man had ordered it, to which the superintendent said, "the old man has gone crazy." He looked me up and wanted to know if I had ordered the breaking box for the

new train solid. I said, "yes;" he replied that if with solid spindles, heavy coupling boxes and solid breaking boxes on top of the rolls, a piece should enter a wrong groove, or a collar should form on the rolls, which was sure to take place, the mill would be broken to pieces; to which I replied: "I would rather have a grand old smash-up once in a while than be continually breaking something and keeping the mill standing half the time and the metal wasting in the furnace." He said: "Well, you will get it, sure;" but we did not, and, as before stated, the mill made 30,000 tons of rails without a break of any kind, which, at that time, on iron, was nearly a year's work.

The heating furnaces were rebuilt, making them larger, the roofs much higher, and the length of the furnace greatly increased, which about doubled the work that had previously been done. There were also a number of improvements made on the train to facilitate the work, and make it much easier for the men. Among them was the introduction of the driven feed-roller, out of which, later on, came the blooming table, which is now indispensable in the rolling of steel ingots either on a three-high or reversing mill.

In 1864 the Bessemer process was introduced in this country. Its introduction and perfection will ever remain one of the most interesting epochs in the history of the iron business.

As already stated, the forge carpenter and millwright were superseded by the machinist. Immediately after the introduction of the three-high mill all the rail mills in the country were changed, and all the new ones that were built adopted the same plan. In fact, as Mr. B. F. Jones, one of the oldest, one of the leading and one of the most practical and successful ironmasters in the country, and one of the very first to see the advantages of the system, said to me a short time since, it was the commencement of the great improvement which took place in the iron works after 1857 which paved the way for the introduction of the phenomenal "Bessemer" process, which, as the Hon. Abram S. Hewitt says, takes its rank with the great events which have changed the face of society since the time of the Middle Ages.

At this time the machinists before alluded to were called to the front to brave the danger and fight the great battles that have ever to be encountered in the introduction of new metallurgical processes, and in none were the difficulties more alarming and disheartening than in the Bessemer process. These men had now received a training which eminently fitted them for the duties they were called upon to perform. Having been inured to hard work, they entered into this new field with such an amount of energy and determination that it made failure impossible.

In witnessing the beautiful and interesting but simple process of blowing a heat of metal, and the regularity with which it is done at this time, and the quantity turned out, it is impossible for one wholly unacquainted with its early history to even in a measure realize the fear and anxiety of those who were responsible for the result. When a charge of metal was poured into the vessel our anxiety commenced, and as the heat increased, our anxiety increased in a corresponding ratio, until both became intense. It was when the heat was greatest that accidents were most likely to happen. The refractory material with which the converters were lined, especially the bottoms, would become plastic, and when in that condition the effect of the heat and the blast would waste the tuyeres and bottoms away so rapidly that from one to three heats were all we could get off of one bottom. Frequently they would give out at the first heat, then out would come the metal through the bottom; and having to use much water about the converter, the place under the vessel was at all times wet, and the result was explosions, often very dangerous, as the hot metal was blown in all directions, frequently inflicting serious injuries on the workmen, a calamity greatly dreaded and the cause of the gravest anxiety to those in charge. When an accident would occur anywhere about the works the first question asked would be: "Is any one hurt?" If not we would go to work at once to repair with that object only in mind. If, on the contrary, some of the workmen were killed or seriously injured, it was impossible to describe the distress of mind that the person in charge had to endure. The anxiety

one had when the charge was put in the vessel was increased with the heat until the heat was blown; but it did not end with the blowing of the heat. When the vessel was turned down it sometimes went too far and some of the metal ran out, resulting frequently in a grand pyrotechnic display of an exceedingly dangerous character. The next operation was to get the metal in the ladle, which was generally not a very difficult one, but it would frequently burn through the ladle, and then the only thing that could be done was to let it run into the pit and order all hands out of the way, for fear of an explosion. As soon as the metal was set all hands commenced to clean the pit, which was no easy task. Here were eight tons of molten steel in the pit burned fast to ingot moulds, bottom and sides of the pit, and to everything that would not burn up. If we were so fortunate as to get the ladle over the pit in good shape our anxiety was not yet at an end. It quite frequently happened that the stopper would pull off the end of the rod; then we had to use what we called a pricker to open the nozzle from the bottom. If the metal happened to be cold, which at that time it was apt to be, the nozzle would freeze up, as we called it; then the metal would have to be poured out of the top of the ladle into the mould, cinder and steel all together, with the result that generally the most of it got into the pit; then, again, if we escaped an explosion we still had a mess in the pit. Altogether the difficulties we encountered were enough to appall the bravest hearts. My brother George once said, when at Cambria, that he did not believe there was a man who ever went into the Bessemer business, and was responsible for the result, who did not at times wish he had never gone into it; and so far as my experience goes I can fully verify it. And, further, I think that, if it had not been for the interesting and exciting character of the business, but few men would have been willing to endure the trouble and anxiety and to endure the physical labor and danger to which he and the workmen were constantly exposed long enough to have placed the business on a commercial basis.

Having alluded to the trouble we had with the converter

tuyeres which caused so much anxiety and loss of time, I will now explain how we got over the difficulty at once. We were only getting from two to four heats off of a bottom and then would have to turn the vessel down and put in tuyeres during the blow. It so happened that, at a time when we were having more than the usual trouble, the vessel was turned down and we were putting in two tuyeres when I was sent for, to go to the blast furnace, there being trouble there. As soon as the vessel was turned up I started for the furnace, not in the serenest state of mind; on the way over I was thinking over some new device for making the bottoms so that they could be burned in order to make them harder and better able to resist the action of the blast, as I had been thinking that that was one of the troubles. As I went into the furnace I noticed some firebricks about 5 inches square and 16 inches in length, such as are used in blast-furnace lining. At once I ordered some of them sent over to the converting department, and as soon as I could I went over and had one of them placed on end in the bottom between the tuyeres and well rammed in with ganister, put in the oven and well dried and put in the vessel. Result: Twelve heats off of one bottom.

From this time our troubles began to diminish, and instead of making ten and twelve heats per day we soon ran up to fifty and sixty heats in twelve hours, and some of the works are now making seventy and eighty. This system of making bottoms was at once generally adopted, and is still in use.

I shall now return to the rolling mill. As already stated, with the introduction of the three-high mill in 1857, the commencement of the great improvement in rolling mills and machinery connected with them took place. The rolls were made larger in diameter, better fitted up, and a more powerful and a much better class of engines was introduced, larger and better heating furnaces were built, and many labor-saving devices were introduced. But with the marvellously increased production of Bessemer steel it was evident that a larger ingot must be used in order to prevent congestion in the pit furnaces and rolls. This, of course,

involved the building of larger, heavier and more rapid working machinery.

In 1868 the lamented Holley, who later on became the consulting engineer of the Bessemer works and so remained until his death, and to whom the country is largely indebted for the introduction of the Bessemer process and for many improvements and important suggestions in the art, built a three-high blooming mill at Troy, N. Y. This mill had the top and bottom rolls stationary, the middle roll being moved up and down, to suit the work, by four screws passing through the bearing carrying the rolls. In the bearing there was a thread corresponding to the thread on the screws, which screws were driven by power. He also had lifting tables, front and back, fitted with loose rolls, and the ingots were pushed into the rolls by hand both in front and in back.

In 1871 my brother George, then superintendent of the Cambria Works, built a three-high blooming mill in which the middle roll was stationary and the top and bottom ones movable, with feed tables both front and back, and the rollers driven by power taken from the train. He also introduced what is called a "pusher" to adjust the ingot in a proper position on the table and also an arrangement for moving the ingot on the table in proper position to enter the rolls.

In 1872 we built at Bethlehem, Pa., a three-high mill in which all the rolls were fixed, with tables similar to those at Cambria, but driven by an independent power which very much simplified the arrangement of driving the tables. This is the plan of mill that was generally adopted, and for a moderate sized ingot and quick working is probably the best plan of mill. But for heavy ingots and for variety of work the reversing mills are preferable.

The rail trains are, with two exceptions, three-high, with larger rolls, very heavy housings and fittings, and more powerful engines, and generally have some kind of labor-saving device attached to the rolls. In fact all the modern rail mills have introduced labor-saving machinery to such an extent that there is, comparatively speaking, but

little left for man to do. This is to a great extent due to the introduction of steel, as it rarely either splits or cracks in rolling, while iron is ever liable to do both, which renders the use of delicate automatic machinery more difficult in rolling iron than in rolling steel.

Many instructive, interesting, annoying and amusing incidents which might be related occurred in connection with the almost magical developments which took place in the manufacture of iron and steel during my long association with the business. But time will not permit.

We left the blast furnaces in 1840, which, as before mentioned, was the commencement of the use of mineral coal, from which period the greatly increased production commenced. While there was no practical change in the principle of making pig iron, yet, the continued increase in size of the furnace, the increased pressure and quantity of blast, the introduction of the Whitwell system of fire-brick stoves, the better understanding of furnace working, the increased knowledge of the chemistry of pig-iron making—all these, coupled with the indefatigable determination of the men in charge, have contributed to bring about the unprecedented and phenomenal production which has so amazed the iron makers of the world.

In 1868 the manufacture of acid open-hearth steel commenced; but its progress was slow, and following the Bessemer, this process not being so interesting and exciting, did not command the attention and respect to which it was entitled. The fact that the Bessemer was in the lead and the machinery was already in use, and that the knowledge of refractory material and in the handling of the steel was acquired, made the introduction of the open-hearth process easy compared to the Bessemer. But the fact that it quietly made its way into general use does not in any way detract from its great usefulness, and, with the invention and introduction of the "Thomas" basic process and its application to the Siemens-Martin open-hearth system, it takes rank only second to Bessemer as one of the greatest metallurgical inventions of the age. And taking into consideration the character of our ores and coal, and their geographical location, the supe-

riority of the metal produced by this process, for structural and machine purposes, may cause it in the near future to outrank the Bessemer in value and general usefulness.

When we look back to the commencement of the last half of the present century, and take a thoughtful survey of all the inventions and improvements that have taken place in the arts of metallurgy during this period, the complete reversal of the position that iron and steel formerly held in relation to each other, the superiority of steel over iron in the useful arts, and the immensely increased production which is unparalleled in the history of metallurgy, it seems impossible to fully realize that so great a change could have taken place within so brief a time.

While we have properly received great credit for the unprecedented developments we have made in the iron and steel industry in the United States, we must not forget that it was the inventions of Cort, of Mushet, of Bessemer, of Siemens, and of Thomas that enabled us to accomplish such important results; and to them all civilized nations owe a debt of gratitude for the incomparable blessing their inventions have conferred on society.

Yet how few of us even for a moment think of the trials, troubles, disappointments, mental anxiety and bodily toil these men had to undergo in the perfection and introduction of their inventions, besides suffering the sneers and jibes of those who imagine that an inventor is nothing but a wild enthusiast, and treat him accordingly. The story of many inventors is truly pathetic and none more so than that of the lamented Thomas. The personal side of the story of the inventor of the basic process can only be appreciated by the reading of his life.

It should not be forgotten that England is the birthplace and home of the "Iron and Steel Institute," and much of our success is due to the information we have gained from the invaluable papers read at their meetings and the discussions that followed them. Here I wish to say that I would commit an act of ingratitude should I fail to give credit to the brave and noble workmen who, throughout my long connection with the business, have ever stood ready to

meet any emergency, no matter what the danger or difficulty might be. All that needed to be said was, "Come, boys," but never "Go, boys," and if the difficulties were not insurmountable they were sure to be overcome; and too much credit cannot be given to these fearless and energetic men for the almost fabulous progress that has been made in the manufacture of iron and steel in this country.

Having already intimated that the United States was not the original home of the iron and steel industry, I will again refer to it.

When I look back to my early days in the iron business-long, long ago, probably too long, it brings to mind one of the happiest periods of my life. After my daily labor was done I was free from all care until the next morning. After supper, at half-past six, then a simple meal, I returned to the works and helped the puddler, heater or roller, as the case might be, until about 10 o'clock. At that time the practical men, puddlers, heaters and rollers, were generally Englishmen and Welshmen. After the heats were charged in the furnaces, and while waiting for the charges to become heated, they would get their pipe—"cutty" they called it—and sit down on a pile of pig or puddled iron, as happened to be most convenient, and take their smoke. Having gained their confidence, I would take a seat by them and then they would tell me about the works in England and describe how their mills were arranged, their system of rolling, the principle and construction of their puddling and heating furnaces, and how to work them. As I spent my nights in assisting them to puddle, heat and roll, I gained a very general practical knowledge of the manufacture of wrought iron, which soon became of great value to me; and to the nights spent in the works with these hearty and generous workmen I owe much of whatever success I may have attained in after life. For the kind and generous manner in which I was always treated by them they ever have a green spot in my memory. In comparing this happy period of my life with what I have since many times gone through, it might, with propriety, be compared with the "Elysian Fields."

How little do the younger men that now have charge of our great iron and steel industries know or even think of the severe mental strain, the great amount of bodily toil, the vexation, the surprises, and the disappointments that had to be endured by the men in charge during the erection and perfection of these vast establishments that are now engaged in the manufacture of iron and steel. And, gentlemen, let me here say that this great work was not accomplished by command but by example. It was the men in training, before alluded to, who erected, perfected and put in operation these most marvellous enterprises of the age. And to these noble, brave and energetic men the people of this country owe a debt of gratitude for the far-reaching results they so thoroughly accomplished, and which have already changed the social condition of our vast territory. They have furnished us with a material which for quality and cheapness and the quantity furnished in a given time is without parallel, and could not have been realized by any other known methods. Without it the building of trans-continental roads would have been almost impossible. Had the rails been made in the old way out of the puddled iron, with the increased traffic on the Atlantic ends of the lines, they would be worn out before the Pacific coast could have been reached. The credit does not end here. The reduction of freight rates, owing to the general use of steel rails, is so enormous that it has been intimated by one of our most distinguished public men that the saving alone on the cost of transportation due to the use of steel in the place of iron would, if available, amount to a sum sufficient to pay our national debt in a comparatively short time.

In addition to the use of steel for rails, the Great West is being fenced with steel at a cost that seems almost fabulously cheap, and this product is being used largely for many other purposes. It was formerly iron that was used for structural work, now it is steel; and it has practically superseded the use of wrought iron. Steel is largely used in the construction of all grades of machinery employed in the manufacturing arts. It is the base of our immense in-

land system of transportation. It is this imperial metal that has enabled the engineer to perform the daring and remarkable engineering feats which he has accomplished during the last half of the century, without which they would have been practically impossible. It is the material used in the construction of these monster floating palaces that cross the vast ocean with the regularity of a railroad train.

Fifty years ago steel was a luxury to the engineer. Modern practice of steel-making in the hands of the mechanical engineer, the metallurgist and the chemist has wrought wonders in producing a material which is used alike in the manufacture of articles of the most weighty, the rudest and cheapest grades, and in the construction of the most intricate, the finest and most delicate implements and machinery. And it is boldly asserting its value and importance through every walk of life.

It is to the invention, introduction and perfection of the modern system of steel-making in this country that we are indebted for the education of our people in the scientific, mechanical and metallurgical arts, which has enabled them to erect such manufacturing plants as were necessary to supply our Government with the sinews of war, which made it possible to achieve those glorious victories which at once placed us in the front rank among the nations of the earth.

I will conclude these reminiscences by giving some statistics compiled by the American Iron and Steel Association, which show the wonderful progress that our iron and steel industries have made since 1840, when I started out to learn my trade as a blacksmith and machinist.

PRODUCTION OF ALL KINDS OF CRUDE STEEL IN THE UNITED STATES.

	Bessemer Ingots. Gross Tons.	Open Hearth Ingots. Gross Tons.	All Other Steel. Gross Tons.	Total Gross Tons.
1867	2,679	0	16,964	19,643
1895	4,909,128	1,137,182	68,524	6,114,834

PRODUCTION OF PIG IRON IN THE UNITED STATES.

	Gross Tons.
1840	286,903
1890	9,202,703
Estimated production for 1899	13,500,000

UNITED STATES.

Production of Pig Iron.—The total production of pig iron in the United States in the past eighty-six years is shown in the following table:

TOTAL PRODUCTION OF PIG IRON IN THE UNITED STATES FROM 1810 to 1898.

YEAR.	Long Tons.	YEAR.	Long Tons.
1810	53,908	1874	2,401,262
1820	20,000	1875	2,023,733
1830	165,000	1876	1,868,961
1840	286,903	1877	2,066,594
1850	563,755	1878	2,301,215
1854	657,337	1879	2,741,853
1855	700,159	1880	3,835,191
1856	788.515	1881	4,144,254
1857	712,640	1882	4,623,323
1858	629,548	1883	4,595,510
1859	750,560	1884	4,097,868
1860	821,223	1885	4,044,526
1861	653,164	1886	5,683,329
1862	703,270	1887	6,417,148
1863	846,075	1888	6,489,738
1864	1,014,282	1889	7,603,642
1865	831,770	1890	9,202,703
1866	1,205,663	1891	8,279,870
1867	1,305,023	1892	9,157,000
1868	1,431,250	1893	7,124,502
1869	1,711,287	1894	6,657,388
1870	1,665,179	1895	9,446,308
1871	1,706,793	1896	8,623,127
1872	2,548,713	1897	9,652,680
1873	2,560,963	1898	11,773,934

PRODUCTION OF PIG IRON, STEEL INGOTS AND CASTINGS, AND FINISHED IRON AND STEEL IN THE UNITED STATES FROM 1890 TO 1898 INCLUSIVE.

YEARS.	Pig Iron. Gross Tons.	Bessemer Steel Ingots and Castings. Gross Tons.	Open Hearth Steel Ingots and Castings. Gross Tons.	Total Steel. Ingots and Castings, Including Crucible. Gross Tons.	Finished Rolled Iron and Steel. All Kinds. Gross Tons.
1890	9,202,703	3,688,871	513,232	4,277,071	6,022,875
1891	8,279,870	3,247,417	579,753	3,904,240	5,390,963
1892	9,157,000	4,168,435	669,889	4,927,581	6,165,814
1893	7,124,502	3,215,686	737,890	4,019,995	4,975,685
1894	6,657,388	3,571,313	784,936	4,412,032	4,642,211
1895	9,446,308	4,909,128	1,137,182	6,114,834	6,189,574
1896	8,623,127	3,919,906	1,298,700	5,281,689	5,515,841
1897	9,652,680	5,475,315	1,608,671	7,156,957	7,001,728
1898	11,773,934	6,609,017	2,230,292	8,932,857	8,513,370

Mechanical and Engineering Section.

Stated Meeting, held Thursday, November 9, 1899.

THE PRESSING OF STEEL; WITH ESPECIAL REFERENCE TO ECONOMY IN TRANSPORTATION.

BY HENRIK V. LOSS, M.E.

I. THE FLOW OF STEEL.

It is an ever-true maxim in life and one possessing a special importance in the line of engineering that the only successful methods to be adopted are those that produce the best results with the least expenditure of time and money. From the dawn of history, the examination of implements indicates that, while being both rough and crude, as the necessary result of an undeveloped state of the individual, as well as of the community, their purposes, as indicated by form and material, show, nevertheless, the analytic workings of a mind bent upon producing the best results from the least amount of labor.

The history of our profession is, of course, the history of the world; and the battles incident to the inflexible laws

of evolution, followed by the old, old story of the "survival of the fittest," have both made the above maxim a law, the non-compliance with which carries with it as a penalty absolute failure.

To produce a certain mechanical result means to accomplish a certain amount of work, and, leaving finance out of consideration, two ways are open to effect this end: the exerting of a larger force throughout a shorter space, and a smaller force throughout a greater space.

But, in the course of the industrial competition, the demands upon our profession became greater and greater, calling for the completion of powerful results inside of shorter and still shorter time. This again meant machines which all had to be quick in action and capable of exerting intense pressures. In the design of motors and machines, simplicity of detail and a small number of parts have always been aims of first importance; because, aside from the fact that such meant less first cost and less repairs, the frictional resistances might otherwise at times become so great as to leave the machine absolutely unable to perform the task assigned to it. And it was this call for the quick exertion of large powers, coupled with the desire to reduce all frictional resistances to a minimum, and also, no doubt, to have a machine that should be under the complete control of the operator—all of which, I say, gave birth to the hydraulic press.

I am not here to give you a history of hydraulic engineering, as my subject is the *work*, rather than the *machine* by which the work is done. It is quite safe to assert that the vast majority of heavy hydraulic machines hitherto built have been used in connection with processes, the main characteristics of which involve the flow of metals, and it is inside of this field that I shall bring to your attention a series of experiments which I have carried on at intermittent periods for the last six to seven years.

In pressing steel the operation can be divided into three distinct systems, each one representing separate lines of resistance to the yielding of the material, namely:

(1) When the material to be treated is absolutely free to

flow in any direction, being nowise confined in any die-chamber, as in shearing.

(2) When the material to be treated is partly free and partly confined, as in punching.

(3) When the material to be treated is wholly confined in dies, as when upsetting rounds and squares, or bridge eye-bars; also as when flanging and riveting.

In order to acquire the most possible complete information as to the strains and stresses existing during the different stages of the pressing process, a diagram showing graphically the rising or falling in resistance of the metal will naturally give the most general satisfaction. To rely upon gauges is placing a dangerous confidence when using high pressures, as the water hammer—which always exists to a greater or smaller degree—will quickly ruin them. Besides, a gauge would have to be used in connection with some other additional instrument controlling the stroke of the press, if a complete record is to be secured. Due to these conditions, I have, therefore, adopted in all my experiments the application of a hydraulic reducing cylinder, the small area of which is connected as close as possible to the main operating ram, while to the greater area is connected an ordinary steam indicator. The larger area, as well as the indicator cylinder, have, previous to each experiment, been filled with water, and a connection has been accomplished between the moving dies and the indicator drum. The result is a card, the ordinates of which represent the hydraulic pressure in pounds per square inch to the extent of their lengths in inches, multiplied by the product of the spring number and ratio of reduction in reducing cylinder. The above device is illustrated by *Fig. 1.*

We shall now consider the resistances to the first mode of flow.

The experiments in this field cover an extended series of indicator cards of the shearing of hot as well as of cold material. The hot work represented dimensions varying from 4 x 4 inches to about 10 x 10 inches. The cold work extended over rectangular bars of widths from 4 to 8 inches, and thicknesses of from $\frac{3}{4}$ to $2\frac{1}{2}$ inches. The latter also included

angles of iron and steel of ordinary merchantable sizes. I desire to say in this place that, in dealing with these different experiments, I do not now have the time, nor is it the purpose of the present paper, to give anything like a complete essay of all the detailed results derived, because the

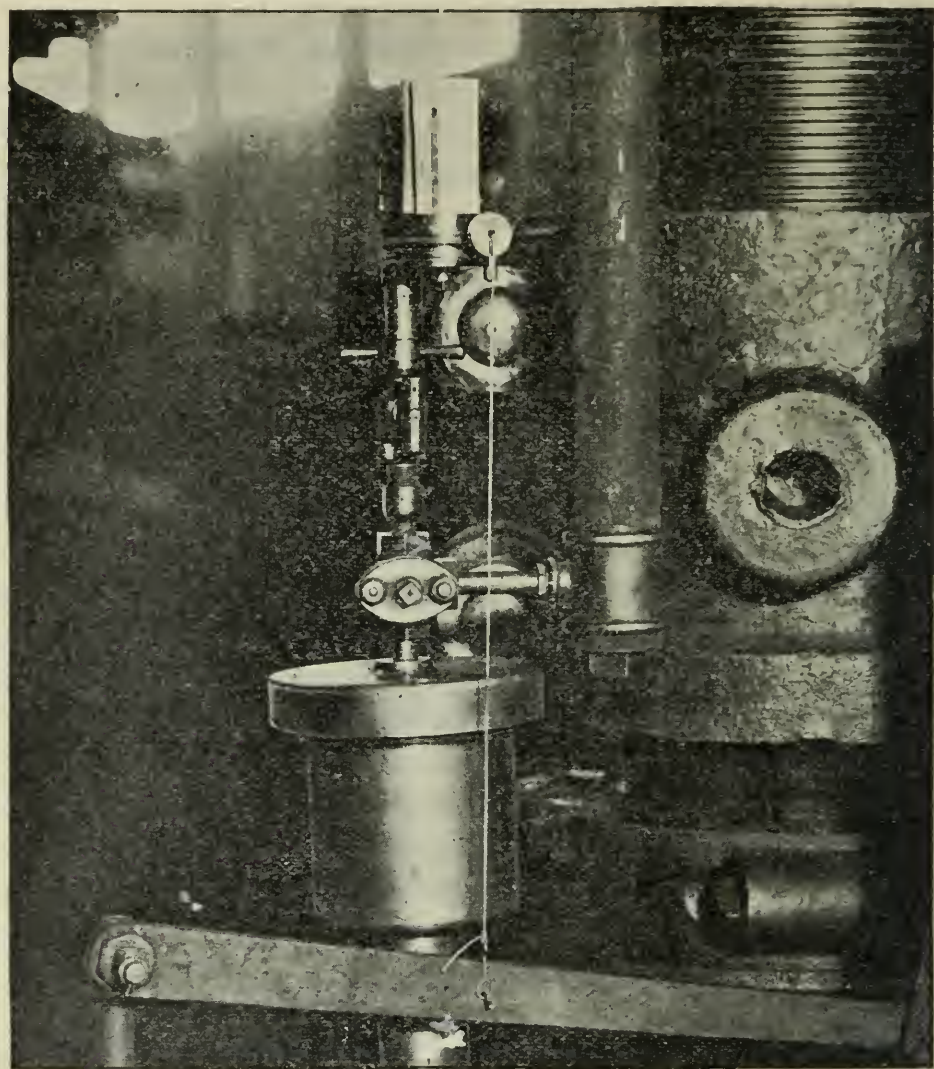


Fig. 1.

indicator cards on each field represent such volumes of interesting information that separate papers can be written on the resistances characteristic to each system. It *is* the purpose, however, to give somewhat of a general view with reference to such figures and pressures that each system de-

veloped, and which might illustrate the duties of the pressing machinery, which the mechanical engineer, in this special branch, may be called upon to design. *Fig. 2* represents typical cards of the shearing of a hot bar. It is seen how the resistances are gradually increasing, finally reaching a maximum at an early stage, and, while afterwards decreasing, are, nevertheless, existing throughout the entire stroke, that is, up to the time the knife has penetrated the entire thickness of the bloom. Both knives were flat, with no back clearance.

The maximum resistance increases as the temperature is lowered, as shown by the different heights and areas of each succeeding card, all having been taken one after the other from the same ingot, as it came from the blooming rolls.

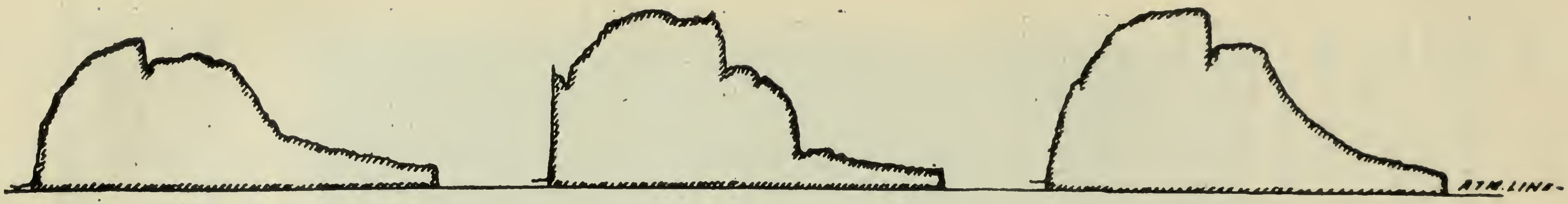
The general results, as far as actual figures are concerned, can be summed up as follows:

Resistance per square inch varies from about 5,000 pounds for a 9 x 9-inch bloom to about 9,000 pounds for a 6 x 6-inch, and reaching about 11,000 pounds for 4 x 6½-inch, which figures all represent steel of about ·20 per cent. carbon, 70,000 pounds ultimate, and at such temperatures which the bloom generally possesses when first reaching the rolls, say about 2,500° F. As it passes through the mill, the bloom gradually cools, and, as the last billet is cut, the temperature is considerably decreased, say possibly down to about 1,800°, and is having its resistance correspondingly increased at a rate of about 50 per cent. for the larger bloom and 100 per cent. for the lesser one.

The energy in foot-pounds at the first cuts varies from 540 for the 9 x 9-inch bloom to 800 for the smaller one, which figures are increased with the decreasing temperature at a rate of about 40 per cent. for the larger dimensions and 75 to 80 per cent. for the smaller ones.

Cards were taken on spring steel with 1 per cent. carbon, possessing an ultimate of 130,000 pounds per square inch. Its resistance and energy when compared to the ·20 per cent. steel were increased about 25 and 14 per cent. respectively.

The local irregularities on these cards are due to the fact



No. 1. No. 2. No. 3.

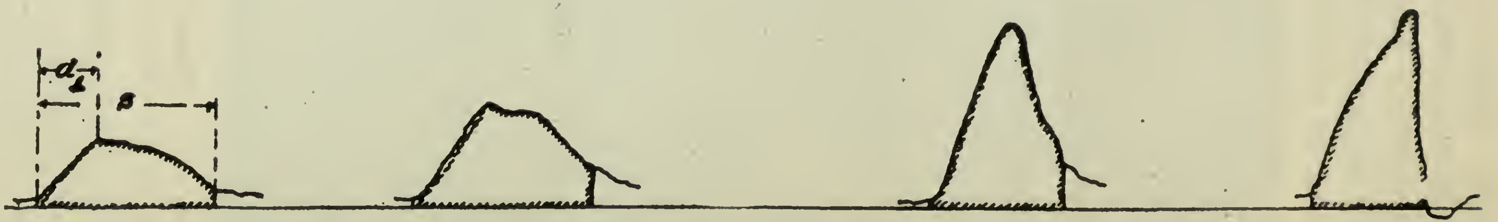
FIG. 2.—6 x 6-inch structural steel.

Maximum ultimate pressure per square inch.

No. 1.	No. 2.	No. 3.
9,000 lbs.	10,400 lbs.	11,000 lbs.

Foot-pounds per square inch of bloom.

No. 1.	No. 2.	No. 3.
800	840	940



8° bevel, iron. 1⅛ inches thick.

8° bevel, steel. 1¼ inches thick.

4° bevel, steel. 1¼ inches thick.

Flat knives, steel. 1⅛ inches thick.

FIG. 3.—Types of cards.

Scale: Horizontal dimensions = full size and 1 inch vertical = 350,000 pounds.

that the hydraulic shear upon which the experiments were made was driven directly by a duplex pump (without accumulator), and the want of uniformity in flow of water from a pump of this kind was naturally transmitted to the indicator needle in the manner as shown graphically.

Fig. 3 represents typical cards of the shearing of a cold bar, and the general outline of such a card will not vary with the form and shape of the bar to be severed. This will be seen shortly, when a card from a steel or iron angle will be thrown upon the screen. The first of the above figures represents an iron bar 5 x $1\frac{1}{8}$ inches, the second a steel bar 5 x $1\frac{1}{4}$ inches, both of these two being cut by a knife with an angle of 8°. The third card was taken from a steel bar 5 x $1\frac{1}{4}$ inches, with an angle of knife of 4°, while the last of all was taken with a flat knife on a 5 x $1\frac{1}{8}$-inch bar. The pressure rose quicker than with hot work, and, the flatter the knife, the earlier in the stroke was the maximum resistance reached. This maximum did also occur at a somewhat later period with an iron than with a steel section, showing in the former a greater distribution throughout the stroke of cutting. It is only fair to assume that this latter feature will be equally in evidence when comparing soft steel to a high-tension material. With flat knives the card becomes very short, indicating, generally, so violent a rupture as to make the needle vibrate quite considerably. The average results on rectangular bars as to actual figures can be summed up as follows:

Necessary pressure per square inch of section to shear a cold bar made from 70,000 pounds steel, and with flat knives, equals about 48,000 pounds.

For an angle of 4° of knife blade the pressure per square inch increases from 36,000 pounds for bars of 1 inch thickness up to 45,000 pounds for 2 inches of thickness.

Within the same limits of thicknesses with 8° blades, the power necessary would vary from about 22,000 to 32,000 pounds per square inch.

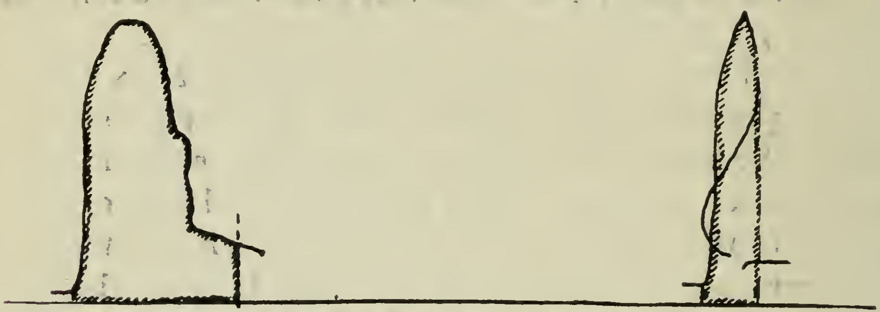
Energy per square inch consumed in cutting rectangular steel bars is as follows:

FOR 1 INCH THICK BARS.

700 inch-pounds for 8° bevel.
1,000 " " " 4° "
1,200 " " " flat knives.

For 2 inches thick bars, the above figures have risen to 1,600-, 2,000- and 2,500-pound inches, respectively.

Fig. 4 represents types of cards of angles, in both cases using flat knives, the first one being taken from a 6 x 6 inches by $\frac{3}{4}$-inch iron angle, and the second from a steel angle, with dimensions of 6 x 6 inches by $\frac{1}{2}$ inch. The same general characteristics are seen to exist here as with the rectangular bars. The average results in figures for cutting iron and steel angles can be placed as follows:



6 x 6 x ¾ inches iron angle. 6 x 6 x ½ inches steel angle.

FIG. 4.—Pressure diagram for iron and steel angles.

The necessary power to cut a steel angle with dimensions of legs, *a* and *b*, and with a thickness *t* is:

$$P = \frac{1}{2} f (a + b) \sqrt{t^1}$$

where *f* is the ultimate per square inch.

The energy per square inch in foot-pounds can be written in the same manner:

$$E = 1600 (a + b) t^2$$

where the letters denote the same as above.

A cold bar, rectangular or otherwise, when exposed to ordinary shearing machinery, as this exists in actual practice, is broken off, and not sheared off. The knife compresses the surface metal, causing the driving force to be distributed on a small area, with a center of pressure located at a small distance away from the line of final rupture.

This distance represents the leverage of the above-mentioned force, and the product equals the resulting bending moment, tending to sever the bar. A large number of experiments were made with the view of determining the position of this center of pressure, and it was found to depend upon the thickness of the bar. Illustrating the above fact, the formula for the flat knife, as worked up on this basis, is represented by:

$$P = \tfrac{3}{5}\, w\, t\, f$$

where P equals total shearing pressure, t and w the thickness and width of bar, respectively, while f equals the ultimate resistance of the material per square inch for flexure. This formula will be found to give good results.

Summing up the general characteristics of the indicator cards, as taken by and derived from the system of pressing metal without any restricting dies whatever, we find the resistances to rise quickly and reach a maximum at an early period, which point being reached, a more or less gradual decrease takes place until rupture occurs. The metal itself will mainly flow in the direction of the pressure, having little or no side flow, while the point of rupture for cold work is always reached before the entire thickness has been penetrated. This point of the stroke, when measured in inches from the time the knife comes in contact with the bar, is represented by the formula:

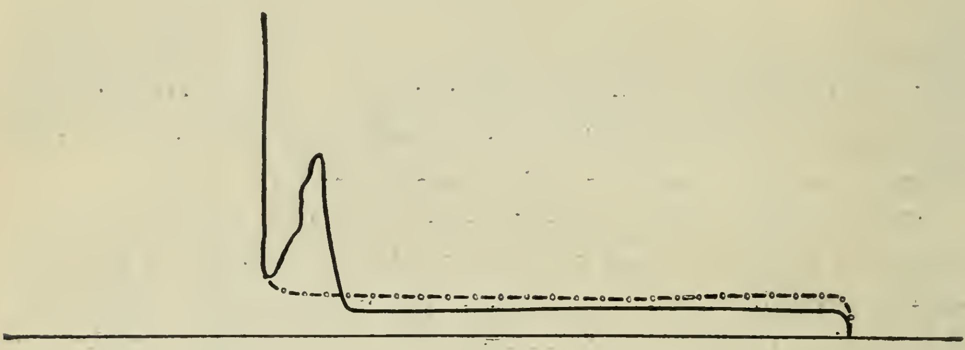
$$s = \tfrac{4}{9}\left(\sqrt[3]{t^2} + w\ tang\ a\right)$$

where t and w equal thickness and width of bar and a represents angle of knife in degrees.

THE SECOND SYSTEM.

It has often been asserted that punching is nothing more or less than a case of shearing with flat knives. That this is erroneous will shortly be seen when a typical punching card is thrown upon the screen. In shearing, let it be remembered that the flow is absolutely unrestricted by any dies, while with punching the metal surrounding the finished hole acts during the operation, by its resistance to flow, partly as the walls of a die-chamber.

In cold shearing the rupture occurs when the bending moment on the bar reaches the resisting moment of the section; while in the case of punching is witnessed the phenomena of a detailed yield of the molecules—the whole process of penetrating through any one thickness being divided, as it were, into periods: the first one representing the resistance to rupture of a certain portion of the thickness, this to be succeeded by a following one where the resistance has become still greater—the line of resistance



1 inch = 600 pounds.
Cold punching.
½-inch steel.
Six $\frac{15}{16}$-inch holes.
No lead.

Reduction = 1:0·37.
Σ = 11,200 foot-pounds.
Σ = 1,300 foot-pounds per square inch of section.

Pressure to lift dies = 75 pounds.
Maximum pressure to punch = 440 pounds.
Maximum pressure to punch = 35,000 pounds per square inch of material.

FIG. 5.

continuously rising until the maximum is passed, after which it very quickly decreases—in quite marked contrast to what exists during the process of shearing, where, as seen by the cards, the heavier resistances are maintained during longer periods, causing diagrams less pointed but more rectangular.

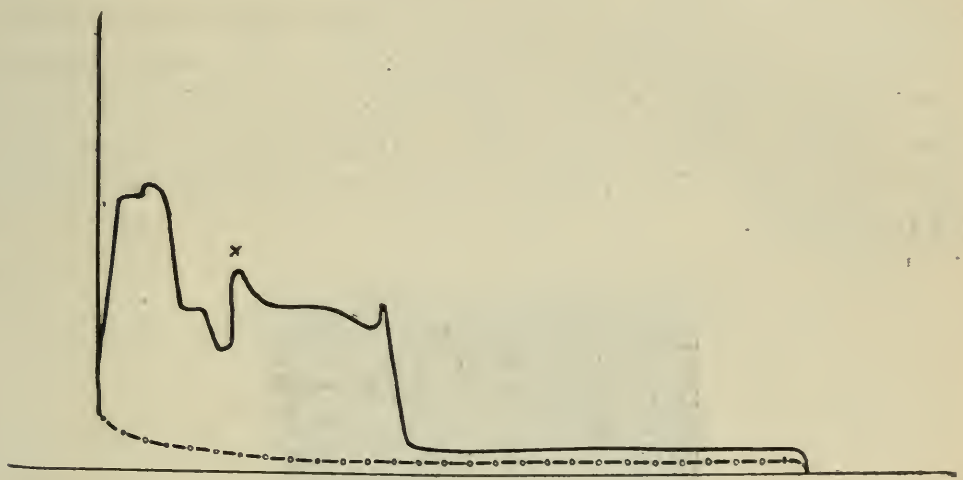
Fig. 5 represents a card taken during the operation of punching six $\frac{15}{16}$-inch holes through $\frac{1}{2}$-inch steel, all tools being square to their axes, and all meeting the plate simultaneously.

When it is desired to punch a very large number of holes the tools are divided up into series, each series being

then set a little in advance of the following one, so as to make the pressure more uniform throughout the entire stroke.

A typical card of this kind is given by *Fig. 6*, which represents the operation of punching two holes, each being $22\frac{1}{2}$ inches long by 5 inches wide, as also twenty-three $\frac{15}{16}$-inch holes, all through $\frac{7}{16}$-inch steel.

The results from a large number of cards on $\frac{3}{8}$-inch, $\frac{7}{16}$-inch and $\frac{1}{2}$-inch materials are as follows:



Reduction = 2·565 : 1.
Σ = 88,000 foot-pounds.
Σ = 1,190 foot-pounds per square inch of severed section for combined shear and punching.

1 inch equals 600 pounds.
Cold punching.
$\frac{7}{16}$-inch steel.
Two holes, $22\frac{1}{2}$ x 5 inches and twenty-three $\frac{15}{16}$-inch holes.
B. & O. cross transoms.

Pressure to lift dies = 75 pounds per square inch.
Pressure at × to finish punching $22\frac{1}{2}$ x 5-inch holes = 490 pounds.
Maximum pressure to punch = 712 pounds per square inch.
1 in 10
Shear on punch.

FIG. 6.

Pressure per square inch to punch 70,000 to 75,000 pounds steel varies from 30,000 pounds to 38,000 pounds, depending upon the condition of the punches.

Average energy per square inch of severed surfaces = about 1,495 foot-pounds, the extremes varying about 10 per cent. each side of this figure.

It must be noted that all the punches were provided

with some shear, as illustrated by *Fig. 7*, which shows the two styles of tools mostly in use. The figures as already given refer to the long punch, the end of which has a shear of $\frac{11}{32}$ inch to the inch on each side of center.

I also made some experiments with the smaller one, which, by-the-by, is *not* the tool generally adopted at our work—and the results with new punches were 38,500 pounds per square inch of section to penetrate the plate. When compared to the former type this is seen to represent an additional power of from 20 to 25 per cent. The average energy per square inch of section for this same type of punch was found to be 1,350 foot-pounds, which is about the same as with the taper tool. Both pressures and energies, especially the former, run very uniform throughout all the tests.

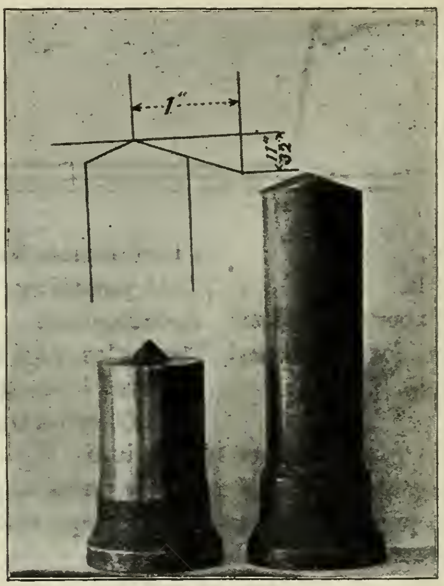


FIG. 7.

The peculiar shape, as exhibited by an ordinary punching, shows plainly the existence of a detailed yield, possessing, in fact, the appearance as if the punch had penetrated two separate plates, originally placed one above the other.

Quite a number of experiments on simple punching (and limited to $\frac{3}{4}$-inch holes and less) were made some years ago by the late Mr. Alfred E. Hunt, of Pittsburg, and a paper on

same was subsequently read before the American Society of Civil Engineers, at their World's Fair meeting in 1893. In comparing notes I find that the energies given in his paper—especially for the greater thicknesses—follow closely the data given above. His pressures per square inch of metal severed run up to those generally assumed for shearing, as he accepts both processes as identical. They are thus about from 50 to 60 per cent. in excess of the results of my own investigations.

The general characteristics of this system are a quick, immediate rise in the molecular resistance in a manner more rapid than that of shearing to be followed by one or possibly more intermittent periods of detailed yield of the solid strata which is nearest the punching tool, the resistance being constantly increasing until a maximum is reached more or less quickly, depending upon the degree of tension of the material. This point being passed, the resistance quickly decreases until rupture occurs upon the penetration of a distance more or less equal to the full thickness of the material, this depending again upon its degree of tensile strength.

[*To be concluded.*]

NOTES AND COMMENTS.

ELECTROPLATED STEAMSHIPS.

The Navy Department has received a full report showing the record of the American steam tug "Assistance," which for four years has been used as an experiment in electroplating with copper as a method of protecting iron ships' bottoms. The iron plates of this vessel were covered by a thin copper coating applied by means of electricity. The "Assistance," after being electroplated, was launched in Jersey City on February 22, 1895, and from that time until a few days ago, she was constantly in the water, and no attempt was made to clean her bottom. Upon being hauled out of the water at the Norfolk Navy Yard the craft was found to be remarkably clean. The bottom was entirely free from barnacles or marine growth of any kind. For the year just past she has been towing in the lower waters of the Chesapeake, and while other tug boats made it a practice to haul out to clean bottoms every four weeks the "Assistance" remained constantly at work.

As a result of the successful outcome of the "Assistance" test it is thought to be quite probable that the Navy Department will order the electroplating

of the bottoms of the new war-ships now building. The electroplating process can be carried out on the plates before they are fitted to the frames. In this process the copper is, figuratively speaking, fused into the steel plates to a depth of about $\frac{1}{32}$ of an inch. The time required to treat a plate is about forty-eight hours.

The cost of applying the copper in this manner is said to be about $3 per square foot. The cost of the method of sheathing now commonly used is about $5 per square foot. By sheathing is meant the English system of planking the outer skin of an iron or steel vessel, countersinking the boltheads, and then fastening copper plates to the wooden planking after the manner followed on wooden ships. If the copper plates were applied directly to the skin of an iron or steel vessel galvanic action would result, hence the necessity of the interlayer of wood. The disadvantages attending sheathing are the increased weight of hull and the disturbance of a vessel's speed lines.

For a vessel 250 feet long there would be required about 20 tons of copper, by the electric process. If covered by the old style sheathing of wood and copper the added weight is more than 100 tons. It has even been found that the use of wooden sheathing between the iron plating and the copper sheathing forms a galvanic pile, as the wood in time becomes water-logged, thus establishing a current between the copper and the iron.

If the process develops no unexpected drawbacks, the value of this comparatively simple method of overcoming one of the most serious difficulties in iron and steel vessels, can hardly be overestimated. It is claimed that as much as $20,000 is yearly expended by various ships in the transatlantic trade as the result of overcoming the added friction caused by fouling. To dock one of the big ships of several well-known lines only twice a year, at $7,500, would bring the total loss per craft up to $35,000 as a yearly penalty for unprotected bottoms. The frictional contact of water against copper is considerably less than against iron, as a painted surface can never be made as smooth as a burnished copper surface. An iron vessel with a speed of twenty knots per hour, if coated with copper, would have, it is calculated, a speed of twenty-one knots per hour.

PRINTING BY X-RAYS.

Dr. Frederick Strange Kolle, in a late number of *The Electrical Engineer*, publishes a description of the "new process of printing by the use of X-rays," which opens up what he claims to be a feasible method of producing an immense number of impressions or records. Dr. Kolle states that printing by the use of X-rays was, perhaps, first suggested by an article by Elihu Thomson in 1896, wherein he showed that multiple radiographs had been made at one exposure; these were called multiple skiagraphs. The experiment proved that more than a single sheet of sensitized paper would be affected by the rays when laid one upon the other, setting aside the theory that the chemical composition of one sensitized film would absorb most of the rays. Owing to the thin sensitized films of the printing paper, very unsatisfactory skiagraphs were obtained. Dr. Kolle now declares that he has overcome these difficulties and that the process of typo-radiography is not a theoretical dream, but is a self-evident and systematic method of procedure. In regard to the practicability of this process, it may be said to overcome first the

cost of labor of composition, secondly, the limited time of striking off copies, and thirdly, the advantage of keeping the entire work a total secret from the printer, a very valuable fact not to be overlooked in diplomatic documents, letters, communications, etc. Dr. Kolle finds a suitable writing ink for this purpose to be composed of red lead, powdered gum arabic, glycerine and water. For type work a semifluid mixture of red lead, potassium bromide, and glycerine sufficient to make a paste would be necessary.

These inks will, however, only permit of white text on a black background unless certain photographic methods are followed, as in the employment of "upset developers," therefore, a second or "unfatty" ink, which will permit of black characters on a white background, must be used. These are made preferably of bichromated mucilage. Bichromated mucilage which has not been exposed to light previous to its use in order that its non-adherent property may be retained, is suggested for the writing. The fatty ink then applied with a roller will adhere to the unwritten portions of the paper, leaving the letters uncovered or free for the penetration of the X-rays. The third method of preparing the phototype is to print or write a text with an adhesive or mucilaginous ink composed of a tacky varnish or gum and then dusting it over with some opaque metallic powder such as mercury biniodide, zinc oxide or lead oxide. The copy would then have to be blown off to render the characters clear cut and the unused space free from mottling opacities resulting from retained dust.

After the copy is prepared, the sensitive paper on which it is to be printed is made into what Dr. Kolle calls a "senso-block," which contains fifty to one hundred sheets. It is then mounted or clamped into a form, the sensitized side upon which the copy or phototype is laid facing up, and it is thus subjected to the action of the X-rays. The current is then turned on for an exposure of ten or twelve seconds, and the block taken to a dark room to be developed. Twenty blocks each containing fifty sheets of paper might be arranged around one X-ray tube to give 1,000 impressions every ten seconds of exposure. This would give about 6,000 copies a minute. Professor Kolle suggests that special gelatino-bromitized films be used and after being photographed to form a block should be made so that it will still retain the features of a single sheet.

The process is extremely interesting, and though it is not regarded as a menace to printing, at the same time there is, unquestionably, a field for the X-ray printing establishment which may only require intelligent development to bring it within the domain of the working arts.

RELATIVE PROPERTIES OF TUNGSTEN AND MOLYBDENUM STEELS.

The production of special qualities in steels, by the incorporation in the metal of relatively small quantities of alloying metals, is attracting much attention from metallurgists. It has, in fact, opened an entirely new field of investigation, which gives promise of yielding extremely valuable results.

Apropos to this is the following communication by Mr. R. Helmhacker, in a late issue of the *Engineering and Mining Journal* relative to the peculiarities of tungsten and molybdenum steels, viz.:

"Steel alloyed with a small proportion of tungsten has been used for some years in the manufacture of tools and other articles requiring a hard and tough metal. Some years ago Prof. V. Leepin, of St. Petersburg, Russia, suggested that molybdenum might be used for the same purpose, as it strongly resembles tungsten in its properties. After some discussion he succeeded in having molybdenum steel made at the Pubilov Iron Works, and carried on a number of tests, the results of which were published in the Russian *Mining Journal* for 1897. In making these tests great pains were taken to have the steel, both tungsten and molybdenum, made under the same conditions. Both steels were made in Siemens regenerative furnaces from a charge consisting for the molybdenum steel of 20·6 kilograms of basic open-hearth steel; 2 kilograms Swedish charcoal pig iron; 2·3 kilograms Swedish charcoal blooms; 0·1 kilogram ferro-silicon, and 1 kilogram molybdenum in a metallic form, but combined with a small quantity of carbon. For the tungsten steel the charge consisted of 16 kilograms basic open-hearth steel; 3·7 kilograms Swedish pig iron; 2·9 kilograms Swedish charcoal blooms; 0·1 kilogram ferro-silicon, and 1·8 kilograms ferro-tungsten having 48 per cent. tungsten. Both steels were cast into ingots, which were afterwards rolled into rods of a suitable size for the testing machine. By analysis the percentage of tungsten was found to be 3·8 and that of molybdenum 3·7.

"The experiment showed that the molybdenum steel is somewhat softer than the tungsten steel. Oil tempering and high heating after hardening increased the limit of elasticity in the molybdenum steel. Common tempering in oil has a greater influence on the tungsten steel than on the molybdenum, but on the other hand the molybdenum steel was stronger than the tungsten after heating and hardening in water. Tungsten steel was more apt to split than the other when worked, and broke sooner when bent cold.

"In many respects the properties of the two kinds of steel were very similar, but the molybdenum steel seems to stand forging and hardening better, showing that in some cases it may furnish a better metal than the tungsten steel.

"We have heretofore referred to the use of molybdenum, tungsten and some other of the rarer metals in the processes for making armor-plate at the Krupp works in Germany and the Creusot works in France. At both these establishments the alloys used are kept secret, but it is probable that a mixture of several of the rarer metals is used, including both tungsten and molybdenum."

A DEPARTMENT OF MINERALOGY AND MINING.

Representative Osborne has introduced into Congress a bill providing for the establishment of an executive Department of Mineralogy and Mining. These subjects in the United States are of such great importance, that there should certainly seem to be a legitimate field for the creation of another department.

"That there shall be established at the seat of government an executive department, to be known as the Department of Mineralogy and Mining, the

objects of which shall be to gather and diffuse among the people of the United States practical and useful information pertaining to mining in all its branches. Said department shall be under the supervision and control of an executive officer, to be known as the Secretary of Mineralogy and Mining. Said officer shall be appointed by the President, by and with the advice and consent of the Senate. There shall be an Assistant Secretary of Mineralogy and Mining. The Secretary of Mineralogy and Mining shall receive the same salary as is paid to the Secretaries of the executive departments of the government. The Geological Survey, as at present established, together with all records, maps and apparatus now connected therewith, shall be transferred to and made a part of the contemplated new department. This act shall go into effect and be in force on the fourth day of March next succeeding the day of its final passage."

RESISTANCES FOR ABSORBING LARGE POWERS.

A contributor to *L'Electricien* describes an ingenious construction of rheostat for absorbing an output of 400 kilowatts used in testing the generators in the station at Nancy, France. The rheostat consists of galvanized iron netting ordinarily used in protecting the underground distribution cables, the particular advantage obtained in using this material apparently being the enormous radiating surface per unit cross-section. A strip of this netting about 11 inches wide, composed of sixteen strands of galvanized iron wire with a cross-section of about $\frac{8}{100}$ of a square inch, the whole strip being 180 feet long, absorbs 500 ampères at 240 volts, the strands remaining at a temperature below that of the fusing point of lead.

Franklin Institute.

(*Proceedings of the Stated Meeting held Wednesday, November 15, 1899.*)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, November 15, 1899.

MR. JOHN BIRKINBINE, President, in the chair.

The chair was taken at 8 o'clock, P.M.

Present, 109 members and visitors.

Additions to membership since last report, 32.

Letters of acknowledgment of election were presented from the following: Rear-Admiral G. W. Melville, U. S. N., Mr. Ralph W. Pope, Dr. Coleman Sellers, Dr. Robert H. Thurston, Dr. Charles F. Himes, Dr. Harvey W. Wiley, Prof. Martin H. Boyé, Dr. T. C. Mendenhall, Hon. Frederick Fraley (honorary members) and Mr. T. Commerford Martin (corresponding member).

A circular of "Directions for Amateur Meteor Photography," issued by the Physical and Astronomical Section for the information of members of the Institute who may desire to make photographic records of the meteoric showers expected to occur about this time, was presented for distribution.

The papers of the evening were then announced.

Capt. E. B. Babbitt, U. S. A., presented a communication on "Recent Developments in Military Powders and Explosives in the United States." The speaker illustrated the subject with the aid of specimens of high explosives now in use in the United States army, and by a series of lantern slides. (Referred for publication.)

MR. A. E. OUTERBRIDGE, JR., in the chair.

Mr. T. D. Mullan presented a communication on "Rubber Substitutes and their Applications to the Arts, with Especial Reference to the Products of the Manufactured Rubber Company." The subject was illustrated by the exhibition of an interesting collection of specimens, exhibiting the new products in all stages of manufacture. Mr. Mullan's paper will appear in the *Journal*. Referred to the Committee on Science and the Arts.

Mr. W. N. Jennings presented a communication of Prof. R. W. Wood, of the University of Wisconsin, on "The Causes of Dark Lightning and the Claydon Effect," illustrated with a number of lantern slides. An abstract of the communication will appear.

The chair expressed the thanks of the meeting to the speakers.

Adjourned. WM. H. WAHL, *Secretary*.

COMMITTEE ON SCIENCE AND THE ARTS.

[*Abstract of the proceedings of the stated meeting held Wednesday, November 1, 1899.*]

PROF. EDGAR MARBURG in the chair.

The following reports were adopted :

Acetylene Gas Generator.—John Condon, Philadelphia.

ABSTRACT.—This machine belongs to the class known as "drop machines," in which the calcium carbide is fed gradually to relatively large quantities of water. This type of machine the Committee considers to be superior in principle to the other two recognized types, *i. e.*, those in which water is added from time to time to large quantities of the carbide; and those in which the carbide is contained in wire baskets and the level of the water rising to or receding from it, is regulated by the pressure of the acetylene gas.

In the Condon machine the feeding of the carbide to the water is made automatic by actuating the feed mechanism by means of the rise and fall of the gasometer. The machine also embodies special devices to ensure safety in charging to prevent the escape of gas.

The Investigating Committee finds that the problem of automatically feeding carbide to water for the purpose of generating acetylene gas has been solved in this apparatus in a satisfactory manner, and that the apparatus is of good construction, well designed and safe in use.

The device is protected by letters-patent of the United States, No. 617,563, January 10, 1899, and No. 687,885, May 13, 1899, granted and assigned respectively to applicant. [*Sub-Committee.*—Chas. A. Hexamer, Chairman; Harry F. Keller, Wm. McDevitt.]

Pocket Recorder for Tests of Materials.—Gus. C. Henning, New York.

ABSTRACT.—The object of this device is to furnish at a reasonable cost a portable autographic recorder, which may be applied to any testing machine which has a running poise weight without causing delay for adjustment, the results being at the same time reliable and such that they can be at once interpreted.

The apparatus consists essentially of three parts: The top and bottom clamps which secure it to the test piece; the parallel-motion mechanism, similar to that employed on a steam-engine indicator, with a pencil at the extremity of the long lever moving at a rate proportional or equal to the stretch or compression of the test piece; and the drum or frame, carrying a sheet of paper on which the record is made, and which moves at a rate proportional to the stress to which the test piece is subjected.

The record is thus a continuous and complete graphical representation of the condition of stress and strain at any and all points between the initial application of stress and the rupture of the test piece.

The investigators find the apparatus to possess the following points of merit: Portability, compactness, the method of gripping specimen, the magnification of the strain in the stress-strain diagram up to the yield point and the normal record from this point on to rupture. The report concludes as follows:

"While not possessing any strikingly new features, the instrument cleverly condenses and combines the strong points of existing appliances, and makes a recorder readily adaptable to any except hydraulic machines." A certificate of merit is awarded. [*Sub-Committee.*—Wilfred Lewis, Chairman; Tinius Olsen, Richd. L. Humphrey.]

Electric Car-Lighting.—Morris Morris Moskowitz, Newark, N. J.

ABSTRACT.—The Moskowitz system belongs to the type of car-lighting systems in which a dynamo-electric machine driven directly from the car axle keeps a set of storage batteries charged, so that each car, when in service, is always in condition to supply its own lights.

[The report is reserved for publication in full.] The John Scott Legacy Premium and Medal is recommended. [*Sub-Committee.*—Arthur J. Rowland, Chairman; E. A. Scott, Chas. J. Read, Geo. F. Stradling.]

Book and Letter Typewriter.—R. J. Fisher.

ABSTRACT.—The apparatus investigated is an improved typewriting machine designed for printing characters on the pages of blank-books, or on loose sheets of paper, by means of steel type and an inked ribbon. [Reserved for publication in full.] The John Scott Premium and Medal is recommended. [*Sub-Committee.*—J. Logan Fitts, Chairman; H. R. Heyl, Samuel Sartain, Hugo Bilgram, Edward F. Moody.]

Static Machine X-Ray Apparatus.—Sweet & Lewis, Boston, Mass.

ABSTRACT.—This consists of a Holtz machine outfit specially designed for the convenient production of X-ray phenomena. The original part of the combination the investigators find to consist in the commutating device, which is made to serve the double purpose of reversing the discharges and of adjusting their frequency and magnitude.

The report concludes that the apparatus is portable, seems reliable and efficient, and in respect of the commutating device is original. A certificate of merit is awarded to the manufacturers. [*Sub-Committee.*—A. E. Kennelly, Chairman; Geo. F. Stradling.]

Portable Photometer.—Charles Deshler and Edwin J. McAllister, Newark, N. J.

This apparatus was described in the *Journal* for November, 1899. (*See* article "Photometry of Incandescent Lamps," Rowland, p. 376.)

The investigators find that the apparatus is well adapted for the purposes of its design. A certificate of merit is awarded. [*Sub-Committee.*—Arthur J. Rowland, Chairman; Francis Head, F. E. Ives.]

Piston-Valve for Steam Engines.—J. H. Dunbar, Youngstown, O.

Steam Turbine.—Samuel Colt, Santa Barbara, Cal.

Brake Mechanism for Railway Cars.—Harper M. Smith, Philadelphia.

Window-sash Slide for Railway Cars and Vessels.—W. Curtis Taylor, Philadelphia.

Electric Motor.—Arthur H. Beard, Philadelphia.

(In these cases the reports were advisory.)

The following passed first reading:

Drawing-Tables.—Samuel J. Loughlin and James Hough.

SECTIONS.

[*Abstract of Proceedings.*]

COMMEMORATIVE MEETINGS, October 2 to October 6, 1899.

The program for the celebration of the Seventy-fifth Anniversary of the Franklin Institute embraced a series of Commemorative Meetings. These were duly announced, and were held in Convention Hall of the National Export Exposition, beginning Monday evening, October 2d, and continuing on successive evenings of the week until Friday evening, October 6th.

The Commemorative Meetings were held in the following order:

CHEMICAL SECTION.—Monday, October 2d, Dr. Jos. W. Richards in the chair.

Mr. John Birkinbine, President of the Institute, made a brief address, apropos to the occasion, in which he sketched the progress of the Institute, and dwelt upon the steady expansion of its work.

Dr. Richards made the introductory address, and presented Dr. Harvey W. Wiley, Chief Chemist to the U. S. Department of Agriculture, who also made an address on "The Relation of Chemistry to the Advancement of the Arts."

Dr. Chas. F. Himes, of Carlisle, Pa., followed on behalf of the Photographic and Microscopic Branch with an address on "The Making of Photography."

(The addresses appear in the *Journal.*)

ELECTRICAL SECTION.—Tuesday, October 3d, Prof. George A. Hoadley in the chair.

The President of the Section introduced Prof. Edwin J. Houston, who delivered an address on "The Seventy-fifth Anniversary of the Franklin Institute from an Electrical Standpoint."

Mr. Ralph W. Pope, Secretary of the American Institute of Electrical Engineers, followed with an address on "The Influence of Technical Societies in Promoting the Progress of the Arts."

(The addresses appear in the *Journal.*)

MINING AND METALLURGICAL SECTION.—Wednesday, October 4th, Mr. James Christie in the chair.

In a brief introductory address, referring to the objects sought to be accomplished by the Section, the Chairman introduced Mr. John Fritz, of Bethlehem, Pa., who addressed the meeting on "The Development of the Iron Manufacture in the United States."

Mr. Chas. Kirchhoff, editor of the *Iron Age*, followed with an address entitled "Three-quarters of a Century's Progress in Mining and Metallurgy."

(The addresses appear in the *Journal.*)

MECHANICAL AND ENGINEERING SECTION.—Thursday, October 5th, Mr. Wilfred Lewis in the chair.

The Chairman made an opening address, dwelling on the operations of the Section and its opportunities for usefulness, and introduced the speaker of the evening, Dr. Coleman Sellers.

Dr. Sellers made an address on "The Progress of the Mechanical Arts in the Past Three-quarters of a Century."

(Presently to appear in full in the *Journal.*)

PHYSICAL AND ASTRONOMICAL SECTION.—Friday, October 6th, Dr. A. E. Kennelly in the chair.

Dr. Kennelly delivered an introductory address, and was followed by Dr. T. C. Mendenhall, President of the Worcester Polytechnic Institute, who spoke on "The Progress of Physics and Astronomy."

(To appear in full in the *Journal.*"

CHEMICAL SECTION.—*Stated Meeting*, Tuesday, November 21st, Dr. Williams, Vice-President, in the chair.

Present, 34 members and visitors.

Dr. Francis Wyatt, of New York, member of the Section, delivered a ecture on "The Influence of Science in Modern Beer Brewing," a carefully prepared and masterly presentation of the subject. Discussed by Dr. H. F. Keller, Dr. Williams and the author. The paper is referred for publication. The meeting tendered a vote of thanks to the lecturer and adjourned.

PHOTOGRAPHIC AND MICROSCOPIC BRANCH.—*Stated Meeting*, Tuesday, November 7th, Dr. Henry Leffmann, President, in the chair.

Present, 44 members and visitors.

Mr. Frank V. Chambers, editor of *The Commerce*, gave an exhibition with the aid of the lantern, of pictures made by the McDonough process of color photography, and gave some explanation of the method.

The subject was discussed by Messrs. J. F. Sachse, L. E. Levy, Fred. E. Ives and Chambers. Mr. Ives gave a brief sketch of the history of this system of producing color effects in photography.

The principal paper of the evening was contributed by Dr. Chas. F. Himes, of Carlisle, Pa., member of the Section, who addressed the meeting on the subject of "Photographic Record Work." Dr. Himes advocated, as part of the systematic work of the Branch, the formation of a collection of photographs preservative of interesting facts—scientific, historical, etc.—otherwise liable to be lost, and the proper arrangement of such a collection for preservation and reference.

The value of photographic work of this kind was illustrated by reference to similar work carried on elsewhere, and was exemplified by the exhibition of photographic reproductions of historically valuable scientific apparatus, ancient MSS., newspapers, etc., contributed by Mr. Sachse, Dr. Leffmann and Dr. Himes. The subject was freely discussed by the members just named, Mr. W. N. Jennings and L. E. Levy. The President announced that the work of preparing a plan for the proper undertaking of such work by the Branch had been confided to a special committee, to report at a subsequent meeting.

ELECTRICAL SECTION.—*Stated Meeting*, Tuesday, November 28th, Prof. Wilbur M. Stine in the chair.

The principal paper of the evening was read by Mr. F. W. Willcox, of the General Electric Company, Harrison (Newark), N. J. Subject: "Incandescent Lamps," and was well illustrated by means of specimens, charts and lantern slides.

Mr. W. E. Harrington followed with a communication on "Rail-bonding," giving the results of practical experience in the use of various methods and conclusions as to the most approved types of such devices.

MINING AND METALLURGICAL SECTION.—*Stated Meeting*, Wednesday, November 8th, President James Christie in the chair.

Mr. Charles James, member of the Section, presented a communication on "The Annealing of White Cast Iron," which embodied the results of much practical experience in this branch of foundry work. A discussion followed on the general subject of iron and steel castings.

MECHANICAL AND ENGINEERING SECTION.—*Stated Meeting*, Thursday, November 9th, Mr. Wilfred Lewis, President, in the chair.

Mr. Henrik V. Loss, member of the Section, read the first installment of a paper on the "Pressing of Steel," treating specially of the flow of steel. Discussed by Mr. James Christie, the President and the author. Referred for publication.

PHYSICAL AND ASTRONOMICAL SECTION.—*Stated Meeting*, Friday, November 10th, Dr. A. E. Kennelly, President, in the chair.

The following communications from the Section's collaborators were presented:

"A brief Report of some late Determinations of the Density of the Earth," by Prof. A. Stanley Mackenzie.

"The Daguerreotype," by Prof. E. A. Partridge.

"A short History and Discussion of the Florentine Enigma," by Prof. C. B. M. Zerr.

A general discussion of the topics followed.